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ORIGINAL ARTICLES.

I.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATE XIX.)

(*Concluded from the June Number, p. 265.*)

Family ROTALIIDÆ.

Sub-family ROTALIINÆ.

Pulvinulina, Parker & Jones.

Pulvinulina repanda (Fichtel & Moll). (Pl. XIX, Fig. 14.)

Nautilus repandus, Fichtel & Moll, 1803 : Test. Micr., p. 35, pl. iii, figs. *a, d.*
Pulvinulina repanda, Brady, 1884 : Chall. Rep., vol. ix, p. 684, pl. civ, figs. 18*a–c*.

Remarks.—This species is recorded from the Tertiary formations of Italy by Parker & Jones and Seguenza, and is still living. Usually it occurs at depths less than 200 fathoms, but is known from 1,000 fathoms (Brady).

Horizon.—Found in B base *c*. Two specimens.

Pulvinulina caracolla (Roemer). (Pl. XIX, Fig. 15.)

Gyroidina caracolla, Roemer, 1840–1 : Verst. n. d. Kreide, p. 97, pl. xv, fig. 22.
Rotalia caracolla, Reuss, 1862 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 84, pl. x, fig. 6.
Pulvinulina caracolla, Chapman, 1897 : Journ. Roy. Micr. Soc., p. 7, pl. i, figs. 9*a–c*.

Remarks.—The species is recorded from the Jurassic (Crick and Sherborn, Journ. Northants. Nat. Hist. Soc., vol. vii, p. 71, pl. vii (ii), figs. 26*a–c*, 1892) and from the Middle Hils and Speeton Clay of North Germany by Reuss. It is unknown in the Tertiary formation.

This is the most abundant species in the Speeton Clay of Yorkshire and the only Foraminifer that has been previously recorded from it. There are specimens named by Rupert Jones in the British Museum and the Museum of Practical Geology. Mr. Lamplugh refers to the occurrence of Foraminifera cemented together in small hard pellets (Q.J.G.S., vol. xlv, p. 596, 1889).

The numerous specimens show a considerable amount of variation. Some have the inferior surface greatly produced into a cone (Pl. XIX, Figs. 15*a*, *b*) with a mass of callus at the apex of the cone. The septa are very thick and the upper surface of the cells relatively thin, so that, when waterworn, a curious mulberry-like form is produced. Practically all the shells are more or less broken, and some of the specimens show the mode of arrangement of the earliest formed

cells. Two varieties exist, microspheric and megalospheric forms respectively (Pl. XIX, Figs. 15*c*, *d*). The dimorphic condition of the allied *P. partschiana*, d'Orb. (*Rotalia pleurostomata*, Schlumb.), was noted by Schlumberger ("Sur le *Biloculina depressa*, d'Orb., au point de vu du dimorphisme des Foraminifères": Assoc. Française, Rouen, 1883 (1884), p. 526), who merely states that there is a great difference in the size of the initial cell in the two varieties of that species. In *P. caracolla* the initial cell in a microspheric shell has a diameter of about ·0088 mm., and in a megalospheric shell a diameter of ·055 mm., or about 6·25 times as much.

Certain specimens show an approach to *P. reticulata* (Reuss), but have not been separated from *P. caracolla*.

The depth at which *P. caracolla* lived is not known, as the species is extinct; but the strongly limbate group of *Pulvinulinæ* to which it belongs are now found at depths of from 70–1,000 fathoms (Brady, Chall. Rep.).

Horizon.—B base *b*, B base *c*, C_2, C_3, C_7, D_2 (base), D_2 (top), D_6. Very abundant.

Pulvinulina lamplughi, sp. nov. (Pl. XIX, Fig. 16.)

Description.—Test free, rotaliform, obtusely conical, the inferior surface nearly flat, the periphery acute and very slightly lobulated. Three convolutions, with usually five segments in the last. Sutures limbate, except the last. The cells, as viewed from the superior surface, are plano-convex, or very slightly concavo-convex in outline. The species belongs to the *P. elegans* group and is isomorphous with *Discorbina isabelleana* (d'Orb.). The nearest ally is *P. carpenteri*, Reuss. Width of test at widest about ·42 mm. (·017 in.). The depth from apex to base is about ·22 mm. (·0085 in.). I have named the species after Mr. G. W. Lamplugh, F.R.S., whose name will always be associated with the Speeton Clay.

Horizon.—Found in B base *c*, C_2, and C_3. One specimen in B base *c*, common in C_2 and C_3.

General Conclusions.

In all forty-four species (one of which has been only generically named, and will not, therefore, be further considered) and one variety have been recognized in the Speeton Clay. Of these, two species and the variety are new. Of the remaining forty-one species, twenty-three are still living, and seventeen of these are known from Jurassic or older deposits, one from the Lower Greensand, one from the Gault, and four from Tertiary deposits. Of the eighteen extinct species previously known, two range from the Jurassic to the Gault, but sixteen have only been found in Cretaceous strata. Including with these the two new species, it appears that eighteen, or 42 per cent, are Cretaceous only. Further, five species, or 11 per cent of the whole, are, so far as is known, confined to Lower Cretaceous beds.

Many species are represented by a single or very few specimens. If we consider not only the number of species but the number of individuals, it appears that the Speeton Clay of Yorkshire is characterized by the great abundance of *Pulvinulina caracolla* (Roemer), which is so plentiful that individuals of this species

are probably at least as numerous as those of all the other species put together. Next in importance, numerically, is *Cristellaria rotulata* (Lamarck), a species which ranges from Jurassic to Recent times and has no stratigraphical value. The genus *Cristellaria* is relatively very abundant, and this genus is characteristically Cretaceous.

As the question of the Jurassic, or Cretaceous, age of the zone of *Belemnites lateralis*, Phil., is unsettled,[1] it is worthy of note that three of the seven species of Foraminifera from that zone are only known from Cretaceous rocks; the other four having a wide range in time.

The number of species in each genus represented in the Speeton Clay is given below, together with the corresponding figures for the Hils of Germany as given by Reuss (op. cit., p. 12). Reuss' classification and nomenclature have been modernized to enable the comparison to be more easily made.

Genus.	Speeton Clay of Yorkshire.	Hils of Germany.
Reophax	1	—
Haplophragmium	1	1
Ammodiscus	1	—
Textularia	1	1
Bigenerina	1	—
Gaudryina	1	—
Bulimina	1	—
Bolivina	—	1
Lagena	3	—
Nodosaria	9	12
Frondicularia	1	2
Rhabdogonium	1	4
Marginulina	4	7
Vaginulina	1	13
Cristellaria	13	22
Polymorphina	2	1
Amphimorphina	—	1
Dentalinopsis	—	1
Pulvinulina	3	1
	16 genera, 44 species.	13 genera, 67 species.

In both deposits *Cristellaria* is represented by more species than any other genus. The next best represented genus in the Hils, however, is *Vaginulina*, but in Yorkshire only a few fragments have been found, belonging to probably at least two species, although only one has been determined. *Nodosaria* is about equally well represented in both deposits, but it is remarkable that *Lagena*, which is fairly common in Yorkshire, has not been recorded from the Hils. Another noticeable difference is the presence of seven arenaceous genera in the Yorkshire Speeton Clay, as against two in the Hils.

Of the forty-four species from the Speeton Clay of Yorkshire, eleven, or 25 per cent, are known from the Hils of Germany. The presence at Speeton of *Rhabdogonium insigne*, Reuss, of the well-marked *Cristellaria gracillissima*, Reuss, both previously known only from the Upper Hils, and of *C. orbiculata* (Roemer), which Roemer described from the Speeton Clay of Germany, but which Reuss did not find, are interesting links between the deposits of the two countries.

[1] G. W. Lamplugh, "On the Subdivisions of the Speeton Clay": Q.J.G.S., vol. xlv, p. 589, 1889.

Compared with the Red Chalk of Speeton (described by Burrows, Sherborn, & Bailey), which is of the same age as the Gault, we find that fifteen out of forty-three species, or 35 per cent, occur in both deposits. If we compare the Speeton Clay with the Gault of Folkestone (described by F. Chapman) we find that twenty-five out of the forty-three species, or 58·5 per cent, occur also at Folkestone. Finally, comparing the Speeton Clay with the Bargate Beds of Surrey, described by Chapman, and of Lower Cretaceous age, there are seventeen out of forty-three species, or 40 per cent in common.

The fact that a higher percentage of species found in the Speeton Clay occurs in the Gault of Folkestone than in the Lower Cretaceous of Germany or Surrey, is to some extent, at least, due to the much greater abundance of Foraminifera in the Gault.

Little can be learnt from the Foraminifera as to the depths of the sea in which the Speeton Clay was laid down. At two horizons only are the species sufficiently numerous to throw any light on this question. Of the thirteen species from B (base) which are still living, four are at present found in water under 100 fathoms in depth. In the case of C_2, of the thirteen species which are still living five are at present found in water under 100 fathoms deep. The remaining species in each case are found in both shallow and deep seas.

Note.—A considerable number of the specimens are found to differ to a small extent from published figures of the species. These differences are too slight to justify varietal names, but in view of their presence it seems desirable to figure the species as found at Speeton. It is interesting to note that in Chalk forms which have been examined these differences are not found, showing that they represent real modifications of the types and are not due to imperfect drawings.

Summary.

1. The Speeton Clay of Yorkshire contains abundant Foraminifera in the beds named by Mr. Lamplugh B (base), C_{10}, and C_2; but the specimens examined from the other subdivisions of F, E, D, and C either do not contain any Foraminifera or they are present in small numbers only.

2. Two new species, *Cristellaria chapmani*, *Pulvinulina lamplughi*, and a new variety, *Lagena apiculata*, var. *danfordi*, occur and are described. Forty-four species belonging to sixteen genera have been found.

3. The characteristic of the Foraminiferal fauna of the Speeton Clay is the great predominance of *Pulvinulina caracolla* (Roemer) over all other species.

4. Twenty-five per cent of the species of Foraminifera occur also in the Hils of North Germany, 35 per cent in the Red Chalk of Speeton, 40 per cent in the Bargate Beds of Surrey, and 58·5 per cent in the Gault of Folkestone.

5. Dimorphism is clearly shown by *P. caracolla* (Roemer). Previously it has been stated to occur among the *Pulvinulinæ* in *P. partschiana*, d'Orb., but no case has been described.

6. Notes are given on the microscopical characters of the sediments.

TABLE I.—Distribution of Foraminifera in the various subdivisions of the Speeton Clay of Yorkshire.

The presence of a species in any subdivision is indicated by the number of the species being placed in the corresponding column.

Species.	B base *b*.	B base *c*.	C1.	Upper C_2(?).	Upper C_3(?).	C7.	C9.	C10.	D2.	D3.	D6 (mid).
1. *Reophax scorpiurus*, Montfort				1							
2. *Haplophragmium latidorsatum* (Bornemann)		2									
3. *Ammodiscus gordialis* (Jones & Parker)				3							
4. *Textularia agglutinans*, d'Orb.		4									
5. *Bigenerina nodosaria* (?), d'Orb.		5									
6. *Gaudryina filiformis*, Berthelin		6									
7. *Bulimina* sp.									7		
8. *Lagena globosa* (Montagu)			8	8				8			
9. *L. apiculata*, Reuss		9	9	9			? 9	9			
10. *L. apiculata*, var. *danfordi*, var. nov.				10							
11. *L. lævis* (Montagu)		11									
12. *Nodosaria* (*Glandulina*) *lævigata*, var. *strobilus*, Reuss								12			
13. *N. hispida*, d'Orb.	13										
14. *N. calomorpha*, Reuss		14									
15. *N.* (*Dentalina*) *siliqua* (?), Reuss		15									
16. *N.* (*D.*) *fontannesi*, Berthelin				16							
17. *N.* (*D.*) *lorneiana*, d'Orb.				17							
18. *N.* (*D.*) *legumen*, Reuss		18									
19. *N.* (*D.*) *communis*, d'Orb.				19							
20. *N.* (*D.*) *roemeri*, Neugeboren				20							
21. *Frondicularia gaultina* (?), Reuss				21							
22. *Rhabdogonium insigne*, Reuss											22
23. *Marginulina linearis*, Reuss				23							
24. *M. glabra*, d'Orb.		24									
25. *M. jonesi*, Reuss	25			25							25
26. *M. debilis*, Berthelin				26							
27. *Vaginulina incompta* (?), Reuss				27							
28. *Cristellaria gracillissima*, Reuss		28									
29. *C. acutauricularis* (Fichtel & Moll)		29	29								29
30. *C. gibba*, d'Orb.				30	30			30			
31. *C. cephalotes*, Reuss	31										
32. *C. scitula*, Berthelin		32									
33. *C. chapmani*, sp. nov.		33		33							
34. *C. crepidula* (Fichtel & Moll)		34		34							
35. *C. turgidula*, Reuss			35	35							
36. *C. cultrata* (Montfort)									? 36		36
37. *C. gaultina*, Berthelin		37									37
38. *C. sternalis*, Berthelin		38									
39. *C. orbiculata* (Roemer)		39									
40. *C. rotulata* (Lamarck)	40	40	40	40	40		40		? 40	40	40
41. *Polymorphina fusiformis*, Roemer		41		41							
42. *P. problema*, d'Orb.				42							
43. *Pulvinulina repanda* (Fichtel & Moll)		43									
44. *P. caracolla* (Roemer)	44	44		44	44	44			44		44
45. *P. lamplughi*, sp. nov.		45		45	45						

TABLE II.—Distribution of the Foraminifera of the

The presence of a species in any deposit is indicated by the

Species.	Range in time as previously known.
1. *Reophax scorpiurus*, Montfort	Jurassic–Recent
2. *Haplophragmium latidorsatum* (Bornemann)	Mid. Tertiary–Recent
3. *Ammodiscus gordialis* (Jones & Parker)	Carboniferous–Recent
4. *Textularia agglutinans*, d'Orb.	–Recent.
5. *Bigenerina nodosaria*, d'Orb.	Miocene–Recent
6. *Gaudryina filiformis*, Berthelin	Gault–Recent
8. *Lagena globosa* (Montagu)	Oolite–Recent
9. *L. apiculata*, Reuss	Lias–Recent
11. *L. lævis* (Montagu)	Wenlock–Recent
12. *Nodosaria* (*Glandulina*) *lævigata*, d'Orb.	Jurassic–Tertiary
13. *N. hispida*, d'Orb.	Lias–Recent
14. *N. calomorpha*, Reuss	Tertiary–Recent
15. *N.* (*Dentalina*) *siliqua* (?), Reuss	L. Cretaceous–Chalk
16. *N.* (*D.*) *fontannesi*, Berthelin	L. Cretaceous–Gault
17. *N.* (*D.*) *lorneiana*, d'Orb.	Gault–Chalk.
18. *N.* (*D.*) *legumen*, Reuss	Gault–Chalk.
19. *N.* (*D.*) *communis*, d'Orb.	Permian–Recent
20. *N.* (*D.*) *roemeri*, Neugeboren (= *D. nana*, Reuss)	L. Cretaceous–Recent
21. *Frondicularia gaultina* (?), Reuss	Gault
22. *Rhabdogonium insigne*, Reuss	Lower Cretaceous
23. *Marginulina linearis*, Reuss	L. Cretaceous–Gault
24. *M. glabra*, d'Orb.	Rhætic–Recent
25. *M. jonesi*, Reuss	L. Cret.–Chalk Marl
26. *M. debilis*, Berthelin	L. Cretaceous–Gault
27. *Vaginulina incompta* (?), Reuss	Lower Cretaceous
28. *Cristellaria gracillissima*, Reuss	Lower Cretaceous
29. *C. acutauricularis* (Fichtel & Moll)	? Lias–Recent
30. *C. gibba*, d'Orb.	Lias–Recent
31. *C. cephalotes*, Reuss	Oxfordian–Gault
32. *C. scitula*, Berthelin	Gault
34. *C. crepidula* (Fichtel & Moll)	Lias–Recent
35. *C. turgidula*, Reuss (= *D. ingenua*, Reuss)	Gault
36. *C. cultrata* (Montfort)	Lias–Recent
37. *C. gaultina*, Berthelin (= *C. cultrata*, B., S., & B.)	Gault–Chalk
38. *C. sternalis*, Berthelin	Gault
39. *C. orbiculata* (Roemer)	Speeton Clay, Germany
40. *C. rotulata* (Lamarck)	Jurassic–Recent
41. *Polymorphina fusiformis*, Roemer (= *P. lactea*, B., S., & B.; = *P. prisca*, Berthelin)	Lias–Recent
42. *P. problema*, d'Orb.	Lias–Recent
43. *Pulvinulina repanda* (Fichtel & Moll)	Mid. Tertiary–Recent
44. *P. caracolla* (Roemer)	Lias–Gault

SPEETON CLAY OF YORKSHIRE IN SOME OTHER DEPOSITS.

number of the species being placed in the corresponding column.

Bargate Beds, Lower Cretaceous.	Germany.							Red Chalk, Speeton.	Gault, Folkestone.	Gault, Montcley, France.	*Challenger* Expedition.	Depth in fathoms now living.
	Middle Hils.	Upper Hils *a*.	Upper Hils *c*.	Speeton Clay.	*Tardefurcatus*-clay.	*Milletianus*-clay.	*Minimus*-clay.					
									1		1	any
									2		2	
3											3	50–2,000
4								4	4		4	
											5	7–1,630
6									6	6	6	to 620
8								8			8	any
9								9			9	any
11								11			11	any
								12			12	50–1,375
									13		13	95–450
								14			14	6–2,200
			15									
16									16	16		
							17		17			
									18	18		
								19	19		19	any
20			20		20		20		20	20	20	under 400
							21	21	21			
		22										
23							23		23	23		
							24	24	24		24	any
25		25							25	25		
26									26	26		
		27										
		28										
29											29	95–2,750
30			30	30				30	30		30	under 500
		31					31					
									32	32		
34		34				34		34	34		34	generally shallow to 2,350
						35	35		35	35		
36											36	rare under 100
								37	37	37		
									38	38		
				39								
40	40	40	40	40				40	40	40	40	any
			41				41	41	41	41	41	to 2,400
42								42	42	42	42	to 155
											43	to 1,000, usually under 200
	44			44					44			

EXPLANATION OF PLATE XIX.

All figures are magnified 50 diameters except Figs. 15*c* and 15*d*.

FIG. 1. *Cristellaria turgidula*, Reuss.
,, 2. *C. acutauricularis* (Fichtel & Moll).
,, 3. *C. sternalis*, Berthelin.
,, 4. *C. cultrata* (Montfort).
,, 5. *C. scitula*, Berthelin.
,, 6. *C. orbiculata* (Roemer).
,, 7*a*–*c*. *C. chapmani*, sp. nov. 7*a*, lateral aspect; 7*b*, the same differently illuminated; 7*c*, oral aspect.
,, 8. *C. crepidula* (Fichtel & Moll).
,, 9. *C. gibba*, d'Orb. 9*a*, lateral aspect; 9*b*, oral aspect.
,, 10. *Vaginulina incompta* (?), Reuss.
,, 11. *Frondicularia gaultina* (?), Reuss. Broken specimen.
,, 12. *Polymorphina fusiformis*, Roemer.
,, 13. *P. problema*, d'Orb.
,, 14. *Pulvinulina repanda* (Fichtel & Moll). 14*a*, superior aspect; 14*b*, inferior aspect.
,, 15. *P. caracolla* (Roemer). 15*a*, thin specimen; 15*b*, thick specimen; 15*c*, broken specimen showing megalospheric commencement, × 42; 15*d*, broken specimen showing microspheric commencement, × 42.
,, 16. *P. lamplughi*, sp. nov. 16*a*, superior aspect; 16*b*, inferior aspect; 16*c*, peripheral aspect.

II.—The Sgùrr of Eigg.

By E. B. Bailey, B.A., F.G.S.

(PLATE XXII.)

THE Sgùrr of Eigg first attained to geological prominence in 1865, when Sir Archibald Geikie in his delightful account of the *Scenery of Scotland* offered a novel and altogether captivating theory to account for its origin [1].[1] According to Geikie, as all well know, the precipitous ridge of pitchstone, which culminates at its eastern extremity in the Sgùrr, is the inverse of an ancient valley sunk by a winding river in the basaltic plateau of the west. Before the development of this river channel, so the theory runs, the sources which had supplied the basalt lava of the plateau had already become extinct; but volcanic activity was not yet entirely banished from the region, and presently a great outpouring of acid lava, entering the valley, flowed for miles along its course, gradually choking it, perhaps even to the brim. The resulting pitchstone has stood the test of time much more securely than the neighbouring basalts, for while these latter have wasted to a level in general lower than that of the old valley floor, the pitchstone itself still remains in large measure unaffected, and thus furnishes a somewhat battered cast of the erstwhile hollow.

The artistic appeal of Sir Archibald Geikie's conception has been admitted on every hand; but, very properly, its credentials have been subjected to a dispassionate and searching scrutiny. In 1906 Dr. Harker, after mapping the district for the Geological Survey, published an alternative interpretation of the pitchstone ridge [3]. We are now asked to abandon the cherished notion of a lava moulded upon the uneven contours of a river valley, and to accept instead that of an intrusive sill irregular and transgressive in its own right.

[1] Footnote numbers in square brackets refer to Bibliography, p. 305.

R. L. Sherlock, Del. ad nat. *Benrose & Sons Ltd., Collo.*

Foraminifera, Speeton Clay, Yorkshire.

The rumour that the familiar theory had been set aside by so competent an authority created a feeling akin to consternation. Accordingly in 1905, before the publication of the paper just referred to, Dr. Peach joined Dr. Harker in a re-examination of the crucial sections.

Dr. Peach started with a predisposition in favour of Geikie's position, but returned fully convinced by Harker's demonstration of the alternative hypothesis. However, quite undeterred by this notable conversion, Sir Archibald Geikie maintained a position of uncompromising hostility when Harker delivered his paper before the Geological Society of London [3, Discussion, p. 67].

Under these circumstances several of us have experienced a not unnatural desire for personal contact with the evidence. In my own case this desire has now been gratified, for I spent a large part of three days last September reviewing the phenomena upon which Geikie and Harker have concentrated our attention.

There is no excuse at the present stage for a further detailed account of the Sgùrr. What I propose is merely a discussion of Dr. Harker's paper. I am certain that readers will share my gratitude to Dr. Harker himself for allowing me, with the sanction of the Council of the Geological Society, to reproduce Figs. 1, 2, and 3, which have already appeared in the pages of the Quarterly Journal. To Mr. A. Stenhouse we are equally indebted for a hitherto unpublished photograph (Pl. XXII, Fig. 1), which I consider an ocular demonstration of one of Harker's main criticisms of Geikie's description. To Mr. Rhodes, jun., we owe the microphotograph (Pl. XXII, Fig. 2) taken from a specimen collected by myself and now deposited with the Geological Survey; this microphotograph will probably induce many to join with the present writer in accepting Geikie's interpretation as essentially correct, in spite of the error alluded to above.

Internal Intrusion Phenomena.

Sir Archibald Geikie in his early descriptions, and also in his reply to Dr. Harker's criticisms, has laid great stress upon the quite definite stratification of parts of the pitchstone ridge. The interpretation he offers is that the acid lava filled up the old valley in recurrent superimposed sheets of pitchstone and porphyry. In this particular Dr. Harker has furnished an important correction which I am prepared to endorse without reservation. He points out that the supposed porphyry lavas (Harker uses the term felsite) are in reality intrusions cutting the pitchstone mass after the latter, in consolidating, had assumed its columnar jointing (Text-fig. 2). A particularly convincing example of this relation is illustrated in Mr. Stenhouse's photograph (Pl. XXII, Fig. 1). The porphyry or felsite of these intrusive sills is of essentially the same material as the pitchstone itself; the difference is that the former has a more stony, the latter a more glassy, base. Dr. Harker emphasizes the close connexion of the two rock-types by an important observation which, in the limited time at my disposal, I left unchecked. He finds that certain of the definitely intrusive felsite sheets, when followed along their outcrop, merge by insensible gradations into the

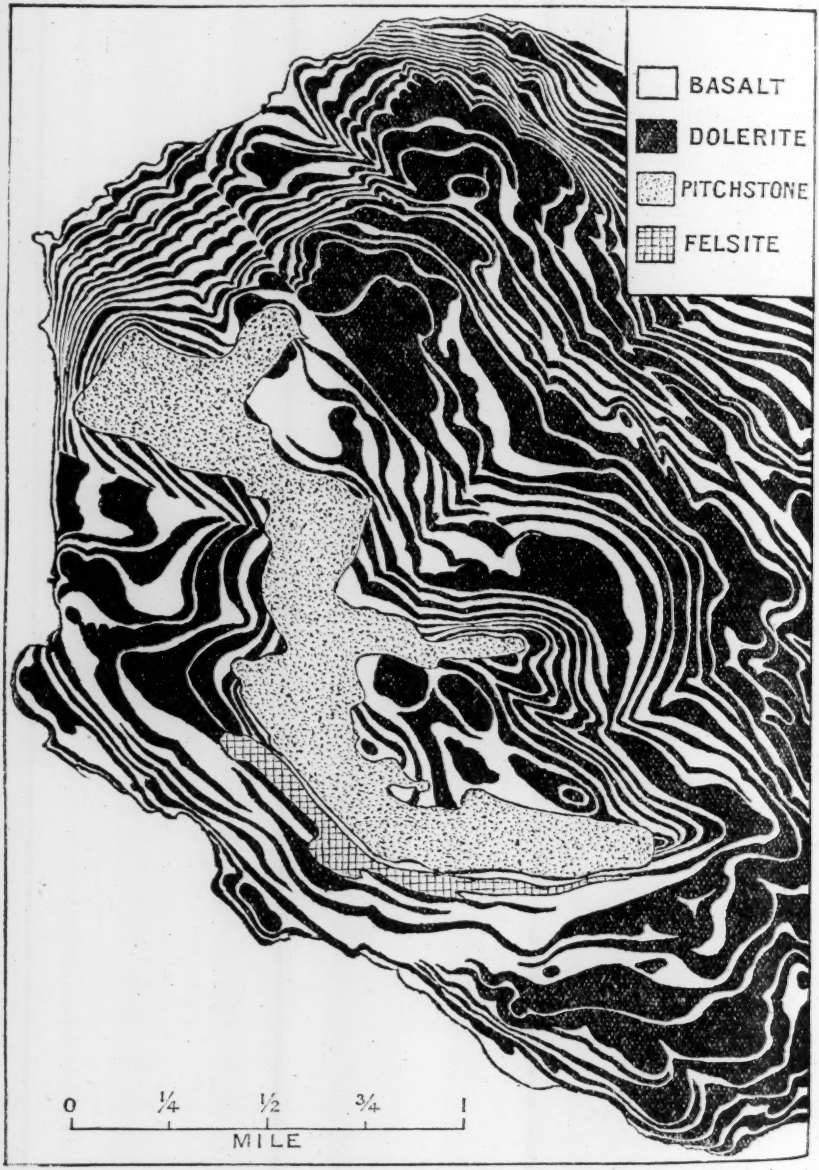


FIG. 1. Sketch-map of the south-western part of the Isle of Eigg, on the scale of 2 inches to the mile. After Harker [3, p. 44].

The felsite shown in this map is quite distinct from the felsite sheets shown in Fig. 2 and described in the text. It forms low ground along with the basalt lavas. The dolerite sheets, indicated by black, are regarded by Harker as sills, by the writer as mainly the interior portions of lava streams.

general body of the pitchstone. I think it may be taken as established that the felsite has followed closely upon the heels of the pitchstone (so far as a distinction can be maintained) and has been supplied from the same source.

There will probably be not a few who will regard this evidence of internal intrusion phenomena as the key to the whole problem, and will agree with Harker in considering the pitchstone-felsite mass a composite sill. I confess that before I visited the exposures I ranked the nature of the stratification of the mass as a crucial point of difference between the two disputants. Now I think otherwise, and remember the late Dr. Tempest Anderson's description of a great eruption of basalt at Matavanu in Savaii, one of the Samoan Islands. The account was given in 1910, when the eruption had been in progress since August, 1905, and the following brief extract will serve as an indication of its bearing upon the matter in hand.

"In the early part of the eruption the lava did not extend far from the crater, the longest streams not exceeding two or three miles, and these did not present the same appearance as subsequently, but were covered with moving scoriæ and stones, so that the whole mountain appeared to be in motion. Later on the lava was often very abundant and very liquid: at times it flowed like a river of water 200 yards wide; at others, as numerous small streams not above 10 feet wide, and in these cases was often so fluid that it nearly all ran away and only left a fresh crust less than two inches thick, over which it was safe to walk next day.

"The large fresh lava-fields soon got crusted over on the surface with solidified lava, and the liquid lava continued to flow underneath. Even at the crater it seldom flowed over the lip, but generally entered holes and tunnels in the sides and flowed underground. The lava-field thus became honeycombed with channels of liquid or pasty lava, which occasionally came to the surface and flooded it with fresh sheets of lava; at other times the surface frequently floated up and was raised by the intrusion of fresh lava underneath, so that what had previously been the course of the valley now became the highest part of the field. Mr. Williams thinks that the lava must be in some places 400 feet thick." [5, pp. 624–5.]

The main lava tunnel at the time of Dr. Tempest Anderson's visit extended as a sinuous line some 10 miles long from the crater to the sea, where it discharged its contents into the sea. Its course was marked at intervals by clouds of vapour escaping from fumaroles. Other fumaroles more to the west indicated the position of a minor subterranean channel.

Let us now turn to a consideration of certain fragmental rocks found in association with the pitchstone, for their importance is, in my opinion, vital.

Fragmental Rocks.

1. A breccia occurs at the base of the pitchstone along the southern face of the ridge for a distance of 500 yards from the eastern termination, and its weathering has given rise to a recess at the foot of the escarpment (YZ, Text-fig. 2). Regarding this breccia Harker writes—

"It shows more or less abundant blocks of the black pitchstone in a soft pale-grey matrix, which is evidently formed by the decay of the pitchstone itself or of its felsitic modification. . . . In addition to the blocks of pitchstone (and felsite), the decomposed matrix encloses in places a few pieces of a blacker

and more completely vitreous rock, without conspicuous felspar-crystals, which may be taken to represent a more perfectly glassy selvage to the pitchstone sheet. There are also fragments of extraneous origin, which are sometimes rather abundant at the base of the pale band, but become rare towards its top. Excepting at one locality, to be described below, these extraneous fragments are exclusively of basalt and dolerite, evidently picked up from the subjacent rocks. The inclusion of these is not necessarily connected with the brecciation, for they are found also in the base of the pitchstone where it is unbroken and unaltered : for example, in the spur on the north-eastern side of the ridge near Loch na Mnà Moire." (Op. cit., p. 47.)

The exceptional locality reserved in the above account for individual treatment is indicated by Z in Fig. 2. Here the extraneous fragments in the basal pitchstone-breccia include not only basalt and dolerite but also Torridon Sandstone and pieces of silicified wood, one of the latter near the bottom of the layer measuring as much as 8 feet in length. The wood is not nearly so conspicuous, however, as might be imagined from Hugh Miller's allusion to a " prostrate forest ".

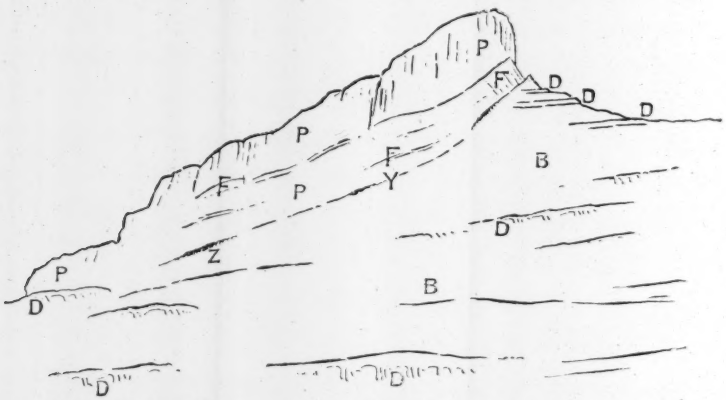


FIG. 2. The Sgùrr of Eigg, seen from the east-south-east, from near Galmisdale. After Harker [3, p. 46].

The lower slopes are of basalt, B, and dolerite, D. The base of the pitchstone, P, weathers into a recess along Y, Z. The pitchstone is intersected by bands of devitrified pitchstone, which may be described as porphyry or felsite, F.

It is easy to account for the presence of such additional foreign fragments at this particular point, for the pitchstone-breccia rests here not directly upon the basalt lavas, but upon a definite breccia deposit made up of basalt lavas and Torridon Sandstone, with fairly abundant pieces of Jurassic sandstone and fossil wood.[1] Beneath is stratified sandstone with a layer of lignite, and beneath this basalt lavas.

For Geikie the breccia deposit and sandstone are the alluvium of the vanished river. For Harker they are an intercalation in the basaltic series. The exposure of the deposit is incomplete, and though

[1] It is by no means certain, however, that the wood in the pitchstone-breccia was not derived directly from growing trees.

it extends for some fifty yards it does not seem possible to the writer to form a definite opinion regarding its relations. What is more immediately attainable is the determination of the precise nature of the pitchstone-breccia. A very thin and irregular representative of this breccia occurs along the steeply inclined base of the pitchstone-felsite complex where the latter terminates in the Sgùrr. A specimen was taken at a point somewhat above the topmost sheet lettered D in Fig. 2. It had the appearance in the hand of being a completely fragmental rock, and as it was fresh—unlike the breccia farther west, which has been weathered to give the recess YZ (Fig. 2)—it was sliced and examined microscopically. The fragmental nature is clearly shown in the slice (Pl. XXII, Fig. 2). The fragments are pitchstone in widely different stages of crystallization, detached and broken porphyritic felspars derived from the pitchstone, and basalt—one small piece of basalt, unlike the others in character, is enclosed in a pellet of glassy pitchstone.[1] A cement of calcite fills the interstices of the breccia.

Some of the weathered breccia of the recess farther west seems to have a definite pitchstone matrix, but some again seems to the eye to be completely fragmental like the specimen just described. At any rate, the occurrence of a genuine fragmental breccia (as opposed to a mere xenolithic rock) at the base of the pitchstone has now been demonstrated, however local the occurrence may be. My own experience leads me to take this as a proof that the pitchstone is a lava. It is a common thing to find definite breccia at the base of lava-flows. In some cases the breccia has resulted from a preliminary shower of ash; in others it is the debris which has slid down the advancing front of the lava. But is it possible to point to any example of an undoubted sill with an open breccia constituting its base?

2. At its north-western end the pitchstone ridge terminates abruptly in a sea-cliff, and there is exposed beneath the pitchstone about a hundred feet of fragmental material (Fig. 3).

With a rope and a trusty companion one could examine at ease the glorious natural section afforded. Like my predecessors, however, I came all unarmed, and had to content myself with hammering over a small part of the fragmental deposit at the south side on the cliff-top. The actual hammering is of course supplemented by the very fine view obtained—especially from the base of the cliff, which can be reached at low-tide after first descending to the shore by a stream-valley some little way farther north.

[1] Anyone wishing to see this xenolithic fragment, which is not shown in the photograph, will find it in a corner of the Survey slice 17181. Dr. Harker, who has kindly examined two additional slices, cut on his suggestion, has drawn my attention to a similar xenolithic fragment on the margin of 17181c. In the two cases the enclosed basalt is of one and the same type, and is markedly distinct from the other pieces of basalt scattered throughout the slices. Dr. Harker (p. 306) states his opinion that in a few cases glass is adherent to these latter also. It is sometimes difficult in a slide of a breccia to distinguish with certainty between mere contact and actual continuity, and I am unable to agree with Dr. Harker in this particular, but fortunately the difference in interpretation does not appear essential to the argument.

Geikie has taken the more obvious course of regarding this fragmental deposit as a river-gravel underlying a pitchstone lava. Harker, assured from the other evidence that the pitchstone is intrusive, holds that the fragmental deposit is an agglomerate enclosed in a funnel-shaped neck which does not pierce the lower lavas of the cliff-face *because it passes behind them*. For Harker the association of the pitchstone and this fragmental deposit is nothing more than a coincidence. So far as the material of the deposit goes, I know of nothing to decide between the two interpretations. The deposit consists in large measure of subangular blocks of vesicular basalt, with a fair proportion of well-rounded boulders derived from the sounder portions of the basaltic flows; small pieces of Torridon Sandstone also occur, but are comparatively rare; fragments of pitchstone are altogether absent.

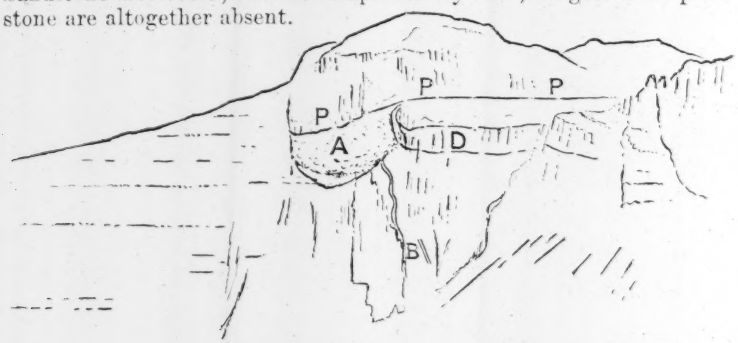


FIG. 3.—Bidein Boidheach, showing the sea-cliff in which the ridge of the Sgùrr terminates north-westward. After Harker [3, p. 53].

The cliff is made of alternations of basalt, B, and dolerite, D, terminating against pitchstone, P, and also against a fragmental rock, A, which Harker regards as agglomerate in a neck, and Geikie as gravel in a river-channel. A particularly massive band of dolerite along the cliff-top, south of the pitchstone and fragmental rock, is lettered D. A basalt dyke, B, cuts the basalt-dolerite succession of the cliff, but not the fragmental rock, A.

A point very greatly in favour of Geikie's reading is the fact that, as seen in the cliff, the pitchstone exactly fits into the upper part of the hollow, in the bottom of which, apparently at any rate, the fragmental material lies (Fig. 3, A). If we accept Harker's hypothesis it is surely remarkable that such a delicate adjustment should occur at any place at all, and doubly strange that the modern cliff should be cut to the precise position requisite to reveal it.

I am very reluctant indeed under such circumstances to relinquish Geikie's interpretation, which accounts so simply for one sweeping curve furnishing the boundary of pitchstone and fragmental deposit alike.

Dr. Harker has gone further than mere suggestion of a possible accidental companionship between the pitchstone and the fragmental material. He believes that he can actually prove that the two belong to widely separate epochs. It is necessary to examine very thoroughly

the foundations upon which he builds, although to do so involves a considerable digression.

The plateau lavas of Eigg show the usual step, or trap, features. Harder bands give rise to escarpments, softer bands to recesses or flat terraces. The harder bands are generally more coarsely crystalline than the softer and are often ophitic, while their exposures show vertical joints which give rise occasionally to perfect columnar structure; such harder bands are Harker's dolerites. The softer bands are finer in crystallization, and typically granulitic and amygdaloidal; these are Harker's basalts (Fig. 1).

Harker's contention is that the dolerites, as a class, are intrusive into the basalts. Naturally, when several years ago Mr. Maufe, Mr. Wright, and I began work for the Geological Survey in the Tertiary igneous district of Mull, we considered this important suggestion very carefully indeed; but neither in Mull, nor Morvern, nor yet in Skye, were we able to adopt it. I make this statement because I wish to disclaim at once any originality for my position in this matter, since I merely hold it in common with most of those, old and young, with whom I have had the privilege of discussion in the field. I also wish to excuse myself for not handling the subject from the general standpoint of Hebridean geology, although my friend Dr. Harker will doubtless feel that a limited treatment is inadequate.

Restricting attention to Eigg, I give the following reason for regarding the great majority of the dolerite sheets of the island as merely the solid cores of lava-flows. In very many representative cases I have definitely followed dolerite merging upward into slag. The vesicular structure starts before the solidarity and the vertical jointing of the dolerite disappears. The transition is perfect. The proof to my mind is rendered complete by finding, in not a few such instances, that the slaggy top has weathered, in large measure, to a red soil before being covered by the next succeeding lava. One may examine successive illustrations of this phenomenon clearly exposed in the precipitous face of Dunan Thalasgair at the northern end of the island. After having seen this convincing section it was pleasant to read in Geikie's description [2, p. 293]—

"Here and there, indeed, between the beds, we not unfrequently meet with a thin irregular seam of red earth, which, when fine, might be called bole. In the cliff below Dunan Thalasgair, for example, several of the dolerite beds are not only covered by this substance, but seem to pass into it." Careful scrutiny left no doubt in my mind of the reality of this passage from dolerite to red earth. The bottoms of the dolerite sheets are in like manner generally vesicular and fairly often brecciated, though to a much less extent than their upper portions.

Now Harker writes [3, p. 41]: "It is to be remarked that sheets of dolerite, in all respects identical with those in question, occur, not only among the basalts, but also among the subjacent Jurassic strata along the eastern coast of Skye and in the northern part of Eigg. Here their intrusive nature has long been recognized. It seems an arbitrary interpretation to make the dolerites intrusive when they occur below the base of the basalt group, and extrusive when they occur above that line." The crux of this argument lies in the premise that the dolerite sheets in the two cases are "in all respects identical". I visited the particular zone of Jurassic rocks, which in Eigg is crowded with basalt and dolerite sills, and found that these sills differed from the dolerite sheets which have been described above in being clearly transgressive and in having *compact chilled upper and lower surfaces*. Similar intrusions occur here and there among the lavas and are quite conspicuous in good exposures; one such may be readily visited south of the pier on the east coast. In all this discussion I find myself in essential agreement with Sir Archibald Geikie's early descriptions of the island [2].

Now let us return once more to the sea-cliff (Fig. 3). Looking at the fragmental deposit it is clear that it includes harder and softer elements, the former often conspicuous as rounded boulders, the latter

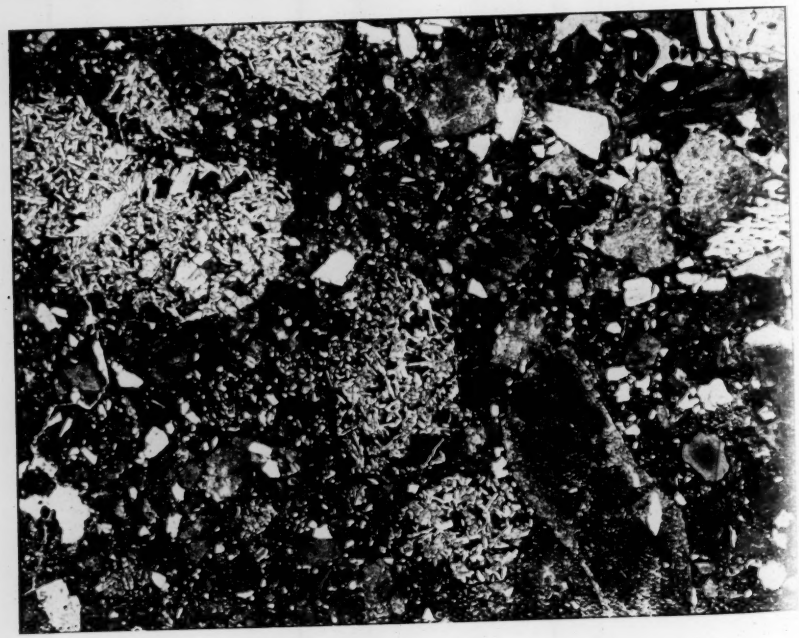
crumbling away to earth. I feel quite confident myself that these harder and softer elements correspond to the doleritic and basaltic material respectively of the lava succession alongside. In agreement with this I found in the accessible part of the deposit dolerite fragments, one big block in particular associated with crumbling amygdaloidal lumps of basalt. But Harker did not notice any dolerite at all [3, p. 54], and accounted for its supposed absence on the view that the deposit occupies a neck which was blown through the basalt lavas before these latter had been invaded by dolerite sills. In fact, the doleritic bands in the lava sequence and also the dyke marked B in Fig. 3 are regarded by Harker as intrusions of later date than the fragmental deposit against which they terminate so abruptly.

The view just outlined was largely based upon an examination of the accessible southern edge of the exposure, where it was thought that clear evidence existed of a dolerite sill being deflected upwards along the steep margin of the deposit. Dr. Harker ascribes this observation to Dr. Peach. I can only say that I consider the appearances relied upon entirely deceptive. Fig. 3 shows the dolerite in question, a particularly strong band marked D. It caps the cliff for some distance south of the fragmental deposit. If it recurs to the north of the latter it must have become considerably thinner in the interval so as to be no longer distinguishable from its fellows. Now, suppose one walks from the south along the edge of the cliff towards the fragmental deposit, one finds that the surface of the dolerite as exposed rises somewhat suddenly just before the deposit is reached. This has given rise to the misconception that the dolerite is deflected upward as a tongue along the junction. But the upper surface of the exposure is in this case merely an accident of erosion: there is no change of texture, no line of vesicles, nor any structure at all that I could find, to suggest that the upper surface as seen corresponds closely with the original upper surface of the dolerite sheet. But of more importance than this negative observation are the actual appearances presented at the junction of the dolerite and the fragmental deposit, appearances which seem to have been hitherto quite overlooked. The pebbly material is packed into little hollows in the steeply truncated face of the dolerite. The deposit has not been indurated. The dolerite, even at the contact, maintains its doleritic texture without the least sign of chilling. I left the exposure convinced that this dolerite sheet (whether it be lava or sill I am uncertain) is of earlier date than the fragmental rock, and that the latter has been heaped against it.

Now the bearing of all this upon the point at issue is that Harker claims to have demonstrated that the fragmental deposit is earlier than a suite of dolerite sills, in their turn earlier than the pitchstone; that, in fact, a great epoch of sill-intrusion separated the period of formation of the deposit from the period of the advent of the pitchstone; and accordingly that the conjunction of the fragmental deposit and the pitchstone must be fortuitous. If my criticism is justified, this line of argument can no longer be maintained.

We shall now briefly consider another objection of a very different type.

1



2

Sgùrr of Eigg.

The Form of the Pitchstone.

Dr. Harker writes [3, p. 48]—

"The elongated and curving trend of the ridge, with its projecting arms, seems at first to accord with the supposition that the pitchstone occupies an old valley with smaller tributary glens; and it is also very noticeable that, at the base of the escarpment, the lower surface of the pitchstone has in most places an inward slope."

He then proceeds to point out difficulties in the way of accepting this hypothesis, which, of course, is the one proposed by Geikie. I have not examined all the evidence Harker cites in this connexion, but I did visit the locality to which apparently he attaches most weight. Here a spur of pitchstone running N.N.E. and S.S.W. joins the main ridge near its western termination. Harker's contention is that if this spur is the cast of a tributary valley, then the latter can be shown to have drained uphill at some parts of its course. All that is clear, it seems to me, is that the edge of the pitchstone in this spur does undulate quite sharply in places, just as a road running parallel with a stream constantly rises and falls. For my own part, I am unable to assert the existence of a regular thalweg buried beneath the pitchstone here, but I find no difficulty in imagining that such exists. At the end of the spur the base of the pitchstone, as seen in cross-section, is considerably higher than at the termination of the main ridge in the neighbouring sea-cliff.

Conclusion.

A careful re-examination of the evidence has led me to accept Geikie's interpretation of the Sgùrr of Eigg pitchstone as a lava-stream moulded upon an ancient river-valley.

With Harker, however, I believe that the apparent stratification of the mass is due to injection, and not, as Geikie thought, to the piling of lava-flow upon lava-flow. Certain other criticisms advanced by Harker I have been unable to adopt.

BIBLIOGRAPHY.

1. A. Geikie, *Scenery of Scotland*, 1st ed., 1865, pp. 278–82. For details see [2].

2. A. Geikie, "On the Tertiary Volcanic Rocks of the British Islands": Quart. Journ. Geol. Soc., vol. xxvii, p. 279, 1871.

3. A. Harker, "The Geological Structure of the Sgùrr of Eigg": Quart. Journ. Geol. Soc., vol. lxii, p. 40, 1906.

4. A. Harker, in Sheet 60 of the Geol. Survey 1 in. Map of Scotland, and in the accompanying memoir, *The Geology of the Small Isles of Inverness-shire*, 1908. For details see [3].

5. Tempest Anderson, "The Volcano of Matavanu in Savii": Quart. Journ. Geol. Soc., vol. lxvi, p. 621, 1910.

EXPLANATION OF PLATE XXII.

Fig. 1. Pale felsite or porphyry injections (F of Text-fig. 2, p. 300) cutting darker pitchstone of Sgùrr of Eigg ridge. Photo by A. Stenhouse.

Fig. 2. Basal breccia of Sgùrr of Eigg pitchstone (a little above the top layer lettered D in Text-fig. 2, p. 300). × 14·5 diam. Slice No. 17181. The fragments with network structure are basalt, the rest pitchstone and felspar derived from same. Microphoto by J. Rhodes, jun.

III.—The Sgùrr of Eigg: some Comments on Mr. Bailey's Paper.

By Alfred Harker, M.A., F.R.S.

MR. BAILEY has very kindly permitted me to see his manuscript, and also to examine a specimen and slice of the rock which he regards as a volcanic breccia underlying the pitchstone. Since he attaches some importance to this rock, I will consider it first.

The natural base of the thick pitchstone sheet is made by a band of more glassy aspect, almost like an obsidian. The microscope shows that this, apart from the usual enclosed crystals, is a light-brown glass, free from the crowds of crystallites found in the ordinary pitchstone. Another feature is that it encloses numerous little fragments of basalt. These indeed, with occasional larger pieces, pass up for some feet into the pitchstone, but they are most abundant near the lower surface. Such inclusions, picked up from the contiguous rocks, may occur both in lava-flows and intrusive sills, but, so far as my experience goes, are more frequent in the latter. The obsidian-like band is well seen, fresh and intact, at places on the northern side of the Sgùrr; but elsewhere it is much brecciated, and usually much decomposed in addition. The brecciation is of such a kind that pieces of the normal pitchstone have become mingled with the debris of the more glassy variety. Mr. Bailey has quoted part of my description of this brecciated basal band as it is exposed, in a decomposed state, on the southern side of the ridge. That it is a part of the pitchstone sheet, not a separate underlying deposit, is there clearly demonstrated: see fig. 6 on p. 60 of my paper. Mr. Bailey's specimen comes, I do not doubt, from a part of the same band which is brecciated but not decomposed. The small fragments of basalt in it represent, in my view, the inclusions which always occur in the basal pitchstone or obsidian. In the course of brecciation they have usually become detached from their more brittle matrix; but one or two, as seen in the slice, seem to me to have relics of brown glass still adherent to them, and one is completely enclosed in a shell of glass, a fact which my friend is content to record without comment. For me, therefore, his rock is no volcanic breccia, but merely the brecciated base of the pitchstone sheet. Such brecciation again affords no criterion as between a lava-flow and a sill.

Mr. Bailey next carries us to the west coast, and discusses the fragmental accumulation there exposed in the cliff. This Sir Archibald Geikie regarded as a thick deposit of river-gravel, thrown down (a circumstance requiring some explanation) just where the valley narrowed to a gorge. To me its characters are not like those of a river-gravel, and it is certainly very different from the accumulation seen on the south side of the Sgùrr, with which it was correlated. My own interpretation has been set forth elsewhere. Concerning the thick dolerite sheet seen just south of this spot, I have no new observation to record. I have not visited the locality since Dr. Peach and I saw, or thought that we saw, the dolerite turning abruptly upward on encountering the agglomerate mass. The form

of the pitchstone surface here, with its steep northern boundary, I ascribe to the intrusion ploughing into the agglomerate and occupying part of its funnel. It is for Mr. Bailey, who distrusts coincidences, to explain why, on his alternative reading of the relations, the thick dolerite sheet should select this critical spot for dying out abruptly.

My generalization concerning the intrusive nature of most of the strong dolerite sheets in the region was not based especially upon the mapping of Eigg, though I find it borne out in that island. When I wrote the passage quoted by Mr. Bailey, I had in mind more particularly the fine cliff-sections on the eastern coast of Skye, rendered classic by Macculloch. The close resemblance in behaviour there between the strong dolerite sheets in the basalt series and those in the Jurassic strata below seems to me most striking. It must surely have been noticed by Sir Archibald Geikie when he set down both as lavas. He has changed his opinion as regards the lower sheets, but apparently retains it as regards the higher ones. If any reader is interested in this question, so fundamental in British Tertiary geology, let him turn to Sir Archibald's paper of 1896 (Q.J.G.S., vol. lii, pp. 331–405) and examine the numerous sections by which it is illustrated. My contention is broadly (though I have no personal knowledge of the Faroe Isles) that the sheets there marked by vertical lines are in general intrusive sills. Further, I maintain that this is in some cases proclaimed by the drawings themselves: in figs. 7, 12, 13, 17, for instance, the transgressive behaviour is faithfully rendered. Similar sections may be seen in Eigg; I remember pointing out to Dr. Peach, on the slopes of the Sgùrr, a dolerite sheet cutting obliquely across well-marked flow-lines in a basalt.

It would appear from Mr. Bailey's remarks that he regards chilled edges as one of the criteria of an intrusive sill. For some of my friends on the Geological Survey this matter of chilled edges seems to have become, in these latter years, a kind of cheap and infallible touchstone. Chilled edges, an intrusion; no chilled edges, a lava-flow: it is at least a rule easily remembered. Now, plainly, an igneous rock will have chilled edges if its magma has been rapidly cooled at its boundary. Rapid cooling of the surface is assured in the case of an ordinary lava-flow (I say nothing of freaks like Matavanu), while for a sill or dyke the question is one of conditions. Nor is it difficult to see what some of the conditions are. There is in the first place the temperature of the country-rocks. The principal sill epoch came immediately after a prolonged succession of plutonic intrusions, when the rocks of the whole region, and especially of the neighbourhood of the plutonic centres, had been raised to a considerably high temperature. Cooling must have been a very gradual process; and it is a matter of observation that, in the long succession of minor intrusions (basic dykes and sheets) which followed, sharpness of boundary and all the indications of rapid chilling become marked, and increasingly marked, as we pass from earlier to later groups of intrusions. Tachylytic selvages, for instance, are scarcely seen except on sheets and dykes which cut all other

rocks; and even there any noteworthy development of tachylyte is found only in places remote from the plutonic centres. In the dolerite sills themselves there is an unmistakable relation between the degree of chilling and the distance from the special centres. Indeed, the thing is a feature of the landscape; for any tourist in the Inner Hebrides must observe how the columnar jointing becomes more strongly pronounced as we recede from the gabbro and granite hills.

Another important factor is the varying thermal conductivity of the country-rocks. A basalt dyke, which exhibits strongly chilled edges where it intersects a sound crystalline dolerite, may show only a very slight modification against a decaying amygdaloidal basalt, and absolutely no sign of chilling where it cuts one of the bands of clay or bole. Professor Kendall long ago drew attention to these differences dependent on specific thermal conductivity, and every student of Hebridean geology must have had many opportunities of observing such phenomena. Again, it is true, as Mr. Bailey remarks, that the disputed dolerite sheets are often intimately associated with the bands of red earth or bole; and this is not surprising, for a sill-intrusion naturally follows the plane of least resistance. But when a sill rests on such a blanket, and is covered by another blanket, viz. the scoriaceous base of the overlying flow, it is too much to demand that it shall show evidence of rapid chilling. The appearance of blending of the dolerite with the bole may be seen equally at the edge of a dyke. I am not attempting to set forth all the elements of the problem, but rather to point out that it is not so simple as is sometimes assumed. In such a case, I submit, we are more likely to reach the truth by trying to understand the conditions than by applying a universal formula of the 'rule of thumb' order.

Finally, Mr. Bailey considers the inclination of the lower surface of the pitchstone sheet at certain localities. Since we unfortunately possess no large-scale contoured map of Eigg, this question can scarcely be discussed with profit except on the spot. But Mr. Bailey passes over without notice a point which seems to me the most decisive of all. The sides of every driftless valley in the basaltic region are *conspicuously terraced*, the strong sheets of dolerite standing out beyond the crumbling amygdaloidal basalts. Sir Archibald Geikie's hypothetical valley has nothing of this character. The base of the pitchstone is an irregularly curved surface, for acid intrusions seldom attain to the perfectly conformable habit seen in many basic sills; but the surface is everywhere a *clean-cut* one, passing across harder and softer sheets indifferently. Let any geologist look at the eastward termination of the Sgùrr, or at any good photograph of it, or even at the small outline sketch reproduced in Mr. Bailey's paper: let him compare the pitchstone base with the terraced slope of the hillside below, and pronounce whether the former represents an erosion-surface or, as I maintain, an intrusive junction.

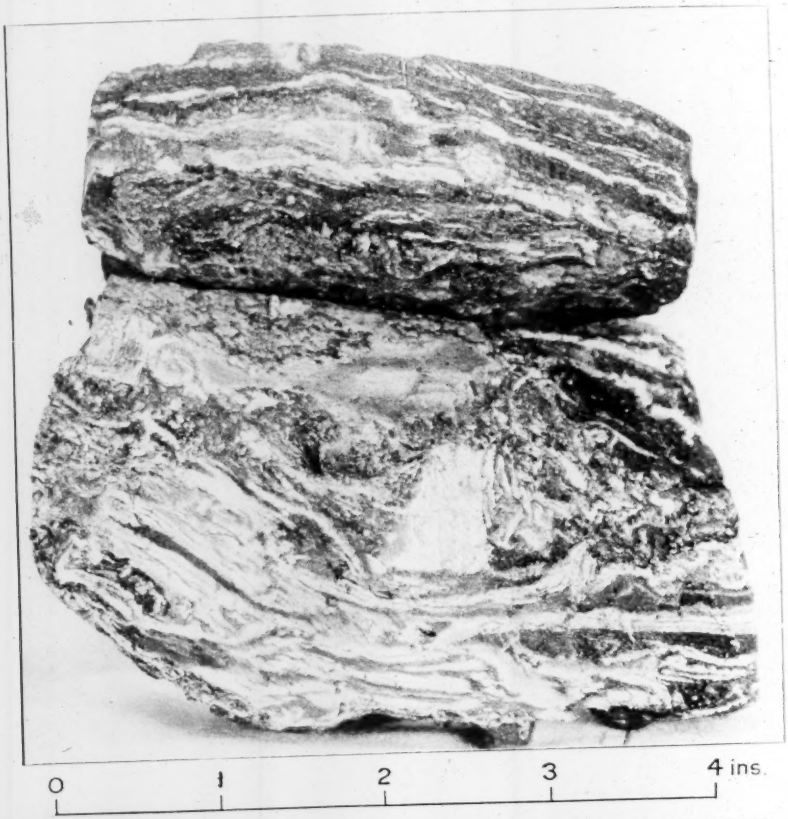


Fig. 1. altered clay from near the granite: Fig. 2. clay about 8 feet from the granite. On land worked by Tekka Co., Ltd.

IV.—The Junction of the Malayan Gondwana Clays with the Mesozoic Granite of the Malay Peninsula.

By J. B. Scrivenor, M.A., F.G.S.

(PLATES XXIII, XXIV.)

ONE of the drawbacks of working in a distant land is that the valuable help of the friendly critic is rarely available, and that, therefore, however strongly the truth of conclusions arrived at may be felt by oneself, it is impossible to expect readers in England to accept without reserve statements that may with perfect justice be said to require corroboration by other observers. I have felt the force of this consideration particularly in the case of the clays of the Malayan Gondwana rocks, which I have described in more than one publication;[1] and as the conclusions in those descriptions are so far removed from what was to be expected in a country where recent alluvium was until quite lately believed to be the most important formation, it is, I think, advisable to place on record in some detail any corroborative evidence that may be brought to light. An additional reason for this course is the constant change in the mine-sections owing to mining operations, and also to the rapidity with which sections weather.

The conclusions put forward in the publications referred to, stated briefly, are that masses of clay in the Kinta district, formerly believed to be recent alluvium, are, as a matter of fact, part of the Malayan Gondwana rocks, that they are older than the Mesozoic granite which forms the Main Range of the Peninsula and other ranges, and that they are of glacial origin. I need not repeat here the evidence already given, and the object of this paper is to present further evidence on one point only, namely the relative age of the clays and the granite. As far as the economics of the country are concerned, the question of the glacial origin of the clays is a matter of no very great importance, nor is it a theory that has been "nailed to the mast" by its author. It best explains the facts seen in the field, but is nevertheless open to objections, and if anyone will produce a more acceptable theory I am ready to give it preference.[2] The proposition that the clays are older than the granite, however, is a matter of great importance from both the scientific and economic standpoint. If it can be proved that these clays are younger than the Mesozoic granite, then the whole argument of a Gondwana cold climate leaving its mark and of a Gondwana tin-field being preserved in the Kinta district would be shattered at a blow. I am confident that it cannot be so destroyed, but it would be wrong to expect others who have not seen the field-sections to share my confidence. I propose, therefore, to describe with the help of some photographs two new sections of the junction between the clays and the granite, which, if they do not remove all doubt on the subject, will at any rate show that to prove the clays younger than the granite would be a very difficult matter.

[1] "The Gopeng Beds of Kinta": Q.J.G.S., lxviii, pp. 140–63, 1912. "Geological History of the Malay Peninsula": Q.J.G.S., lxviii, p. 350, etc., 1912. *The Geology and Mining Industry of the Kinta District*, Kuala Lumpur, 1913, pp. 27–43.

[2] The late Dr. Tempest Anderson saw some of the clays with boulders in 1913, and remarked on their similarity to glacial deposits.

The two sections occur on the east side of the Kinta Valley, one on the land worked by the Tekka Company, Ltd., the other on the land worked by the Société des Étains de Tekka. Both these mines lie to the north of Gopeng (*vide* sketch-map with the *Geology and Mining Industry of the Kinta Valley*).

The Tekka Company Section.

On the Tekka Company's land the Gondwana clay near the granite is of a deep-red colour. Boulders of considerable size are rare in the clay, in fact the only big boulders I have seen in situ on this mine are those of corundum previously described. Lately, however, I have seen some good sections with small boulders bearing a striking resemblance to Boulder-clay. At one part of the mine, newly opened up, the clays can be followed for a distance of about 80 yards right up to a well-exposed junction with the granite, which is here soft owing to its being rich in kaolinite and also to the effect of weathering. Perhaps the kaolinite was partly formed by weathering.

At a distance of about 30 feet from the junction the clay shows no sign of alteration, but within that distance coloured streaks appear, that might in some places be described as foliæ, and increase as the granite is approached, until at the junction the clay, instead of being a uniform deep-red colour, is a roughly foliated and banded mass of red, black, white, and yellow streaks, and is traversed by small, hard veins of blue tourmaline, which are not easily observable until the clay is broken up. Pl. XXIII, Fig. 2, is a photograph of a portion of the clay about 8 feet from the granite. Pl. XXIII, Fig. 1,[1] is a photograph on a larger scale of similar altered clay. The black streaks were found to contain iron and manganese. Mineral matter heavier than 2·8 (specific gravity) separated from the altered clay in bulk was found to be chiefly blue tourmaline, but comprised a few grains believed to be secondary corundum and hercynite.

Near by this section the clay is traversed by white veins which are fairly hard and fine-grained. Some are as much as 6 inches thick, but the majority are smaller than that. Sections and separations show them to consist of white mica and fluorite as a fine mosaic of irregular flakes and grains, with minute grains and acicular particles of corundum that form veinlets in the mosaic, and a small quantity of another mineral believed to be a spinel. The corundum in these veins must not be confounded with the corundum boulders. It was clearly brought into being by the influence of the granite, whereas the big corundum boulders are detrital components of the clay.

The granite junction is irregular and, apart from the evidence of alteration, leaves no doubt in the writer's mind that the granite was intruded into the clay.

The Société des Étains de Tekka Section. (Plate XXIV.)

This section is even better than that just described. In the mine a large intrusive mass of granite with tourmaline veins has been disclosed. On either side, as seen now in section, it falls away at an angle of about 45° and is in part fairly hard. On the north side of the granite a big face of clay has been exposed for some time,

[1] The scale of inches on the Plate refers to the upper figure (Fig. 1).

Junction of clay (C) and intrusive granite (G) on land worked by the Société des Étains de Tekka, Malay Peninsula.

extending from the granite junction about 100 feet. At about 80 feet from the granite pebbly beds are exposed. One of them passes downwards vertically into clay, the pebbles becoming fewer and fewer. From the pebbly beds, which are grey, to the granite the whole section is of deep-red clay with very little stone. At the junction shown in Plate XXIV, as clean a junction between two rocks as one can hope to see, the streakiness observed in the Tekka Company's section is not so extensively developed, but is visible both in the vertical section and in the floor of the mine, where the junction can also be followed. No tourmaline or fluorite and mica veins were seen, but in a section in another mine hard by a vein of blue tourmaline was traced for 40 feet from the granite into the clay.

On the south side of the granite the clay has been largely worked away, but an interesting point is that here one of the kaolin veins I have described elsewhere as traversing the clays was seen traversing the granite. These veins of almost pure kaolinite, without any proved felspar, are of exceptional interest, but this is not the place to discuss them.

The Present State of the Clay at the Junction.

To anyone unacquainted with the effects of tropical weathering a surprising feature of the clay in both these sections at the granite junction would be that it is soft enough to be cut by hand. Shales, and some rocks harder than shales, generally weather to the consistency of cheese in the Malay States, but in every section I have seen the bedding is preserved up to the subsoil. At a granite junction, however, where the latter is clearly intrusive, one would expect some degree of greater hardness. In the case of shales and other rocks this is found, and the lack of it in these clays is, I think, ascribable to two causes. In the first place the clays, although they contain a certain amount of grit, are everywhere rich in kaolinite, and therefore it may be assumed that when the granite was intruded they were very plastic and yielded easily to the pressure of the earth-movements. This would result in the generation of a relatively small amount of heat compared with less plastic rocks, and consequently less alteration. Secondly, supposing silicification had been set up, resulting in an indurated clay, the evidence of the effect of ground-water on the large outcrops of quartzite in the country shows that in the present position of the clays the siliceous cement would certainly have been removed by now.

V.—The Fossils found on the Site of the Torquay Museum.

By A. J. Jukes-Browne, F.R.S., F.G.S., and R. B. Newton, F.G.S.

Part I. By A. J. Jukes-Browne.

THE fossils which form the subject of this notice were obtained from the slates exposed in the excavations for the foundations of the 'Pengelly' Lecture Hall, which was added to the Museum of the Torquay Natural History Society in 1894. They were collected by Mr. W. J. Else, the late Curator of the Museum, and were examined by the late Rev. G. F. Whidborne, who published some account of them in the Geological Magazine for 1901, p. 533.

When Mr. Whidborne's paper was published I was not specially interested in the details of the geological structure of Torquay, but since then I have paid much attention to these local details and have collected fossils from all existing exposures. I was consequently surprised to find on reference to the note published by Mr. Whidborne that he had regarded these fossils as a Lower Devonian assemblage, in spite of the fact that the Museum is in close contiguity to a tract of Middle Devonian Limestone, as shown on the map of the Geological Survey published in 1898. Moreover, he quoted a statement made by the late Mr. A. Somervail regarding the stratigraphical position of the slates which is entirely incorrect. It is not true that in ascending the Torwood valley from The Strand one passes over a descending series of rocks. The beds underlying The Strand are shaly slates, which dip northward under limestone, and the same slates run up the valley to and a little beyond the Museum; they are then succeeded by limestone which crosses the valley in a south-east direction, and about 100 yards higher up this is faulted against slates which are believed to be of Lower Devonian age. There is therefore every reason to suppose that the slates are the Calceola Shales and pass under the adjacent limestone. Another band of similar shale extends from Torwood Gardens to Meadfoot Beach, where it can be seen to pass under the limestone. It should also be mentioned that in his memoir on the *Geology of the Country around Torquay* (1903) Mr. Ussher referred the slates of the Museum site to the Eifelian (=Calceola Shales) without any mention of Mr. Whidborne's opinion about the fauna.

It would require very strong palæontological evidence to establish the existence of Lower Devonian below the Museum, and, though Mr. Whidborne headed his note "Lower Devonian Fossils from Torquay", it would seem that he was prepared to admit a doubt about the matter, for his opinion is expressed as follows: "It will be seen that they may on the whole be referred to the Upper Coblenzien or to a slightly higher horizon." Now the next stage in the French sequence is the Eifelian, or Couvinian as the Belgians prefer to call it, i.e. the lowest part of the Middle Devonian.

The fauna as described by Mr. Whidborne, omitting Corals and Bryozoa, comprised thirteen identified species, and of these nine range up from the Coblencian to the Middle Devonian, but four of them are essentially Lower Devonian and do not range upward. It thus becomes a question whether these four species were correctly identified. Moreover, I found that though Mr. Whidborne had returned the specimens which he had studied to the Museum, only those which he had actually figured were named and mounted. The rest were put away in drawers and only bore small numbers, which probably referred to some list, but about which nothing was known at the Museum nor by Mr. Else. Consequently some of the specimens which Mr. Whidborne had named but had not figured could not be recognized. There were also specimens in a box, and I am informed by Mr. Else that the material examined by Mr. Whidborne did not include all the fossils obtained.

Under these circumstances it was evident that the whole collection needed revision and also that they should be submitted to someone who was specially acquainted with the Brachiopoda, as the majority of the species belong to that class. Application was accordingly made to the British Museum, with the result that Mr. R. B. Newton kindly undertook to examine a selection of the specimens. The whole collection was then sent to me and the best specimens were selected for transmission to Mr. Newton, but I retained most of the corals for further investigation.

It should here be mentioned that all the fossils are either internal casts or external impressions, the actual shells and calcareous parts having been dissolved and carried away by percolating water.

Mr. Whidborne described five species of Anthozoa, but the specimens on which he based three of these identifications could not be found either in the Torquay Museum or in the Sedgwick Museum at Cambridge, to which Mr. Whidborne's own collection was presented. Two of these five species were described and figured, and three were described but not figured, the latter being *Hallia quadripartita*, Frech, *Amplexus* sp., and *Metriophyllum Elsii* (new species, which should be written *M. Elsei*).

Hallia quadripartita was described from two specimens, one from this locality and a better one from "near Walls Hill". Neither of these specimens can now be found. Frech described this as a new species, but Schlüter afterwards identified it as only a variety of his *Aulacophyllum looghiense*, and I think it safer to adopt his opinion.[1]

The second species was identified as belonging to the genus *Amplexus*, from a single distorted cast of the cup, which was about 25 mm. deep by 25 mm. in width with twenty-eight major septa. This specimen cannot now be found.

Metriophyllum Elsei is stated to be the commonest coral in these slates, and there are some thirteen specimens which resemble one another and may belong to the genus *Metriophyllum*, but they are merely casts and most of them are crushed. The number of major septa seems to be from eighteen to twenty and not uniformly sixteen as stated by Mr. Whidborne; they are twisted as they approach the centre, but it is difficult to say whether they formed a pseudo-columella. Dr. Vaughan, who has seen them, thinks Mr. Whidborne must have had before him a better specimen than any of those now in the Museum, which are not sufficiently good for even generic identification.

Besides the corals above mentioned there are four casts among those in the Museum which clearly belong to a different genus. They have the general aspect of *Petraia* or *Streptelasma* and have a strong resemblance to the small Devonian corals which Schlüter has referred to the genus *Duncanella* of Nicholson.[2] In fact, they may be casts of the two species described by him under the names of *Duncanella major* and *D. pygmæa* on pp. 16, 17 of the work above

[1] "Anthozoen des rhein. Mittel-Devon": Herausg. Kön. Preuss. geol. Landes, 1889, p. 32.

[2] "Anthozoen des rhein. Mittel-Devon": Herausg. Kön. Preuss. geol. Landes, 1889.

cited and figured on pl. ii, figs. 9–15, both being from the Middle Devonian limestones of the Eifel.

The two larger Torquay specimens had from sixteen to eighteen straight septa, which did not reach the centre, and an equal number of rather shorter secondary septa, the total being thus from thirty-two to thirty-six septa. There was no columella. The diameter is about 8 mm. and the length may have been about 12 mm. The two smaller specimens are in one piece of slate and have only twenty-eight septa arranged in the same way at equal distances. Their diameter is only 4 mm., and they seem to agree with Schlüter's description and figures of *Duncanella pygmæa*, except that the latter is said to have only twenty-four septa. Dr. Vaughan has seen these specimens and remarks that they appear to be specialized Streptelasmids and that they may belong to *Duncanella*, but as they are casts he does not think it safe to venture on more precise identification.

The two species of corals figured by Mr. Whidborne were a *Pleurodictyum* and a *Cladochonus*. To the former he gave the name of *pachyporoides*, and there seems little doubt that it is really a *Pleurodictyum*, though it has the habit and branching growth of a *Pachypora*. The genus occurs both in the Lower and Middle Devonian. There is also no doubt about the *Cladochonus*, and whether it is referable to *C. alternans* (Römer) or to *C. Schlüteri* (Holz.) matters little, for the genus does not occur in the Lower Devonian, ranging from Middle Devonian to Carboniferous; consequently its occurrence is antagonistic to his opinion regarding the age of the fauna.

Lastly, there are two specimens of *Fenestella* to which Mr. Whidborne gave the name of *torwoodensis*, remarking that "it comes extremely close to" the *F. arthritica* (Phil.) from Hope's Nose. To me it seems really closer to his *F. fanata* from Lummaton, and either way its affinities are with the Middle Devonian forms.

Part II. By R. B. Newton, F.G.S.[1]

The following is a revised list of the fossils from the site of the Torquay Museum, based on a study of the specimens forwarded by Mr. Jukes-Browne. These were believed to include the specimens described by Mr. Whidborne in 1901, as well as a few which had not been examined by him. The Cephalopoda have been determined by Mr. G. C. Crick. The name of Etheridge appended to notes on the distribution of the species refers to that author's *Fossils of the British Islands. Palæozoic*, 1888.

Cephalopoda.

Anarcestes lateseptatus, Beyrich, sp.

This is essentially a Middle Devonian species and does not occur in the Lower Devonian. In Germany it ranges from the Orthoceras shales of Wissenbach (Untere Mittel-Devon) to the upper part of the stage (Obere Mittel-Devon) according to Holzapfel (Abhand. Kön. Preuss. Geol. Landesanstalt, 1895). In England it is common in the bands of shaly limestone which occur in the lower part of

[1] Published by permission of the Trustees of the British Museum.

the Calceola Shales of Mudstone Bay, south of Berry Head, and is associated with *Cyrtoceras bdellalites*, Phil., and *Gyroceras ornatum*, Goldf. (See Ussher, *Geology of the Country around Torquay*, Mem. Geol. Surv., 1903, p. 76.)

ORTHOCERAS SPECIOSUM, Münster.

O. cinctum, Phillips, *non* J. de C. Sowerby.
O. hercynicum (?), Whidborne, GEOL. MAG., 1901, *non* Kayser.

There are three fragments of this species.

Distribution.—Middle and Upper Devonian.

ORTHOCERAS sp.

This is the specimen which according to Mr. Whidborne may possibly belong to *O. ellipticum*, Münster. There is only one fragment, and it shows a central siphuncle.

Distribution.—According to Dr. A. H. Foord, *O. ellipticum* occurs in the Upper Devonian of Germany.

Gasteropoda.

CAPULUS PRISCUS (?), Goldfuss, sp.

Determined and figured by Mr. Whidborne in GEOL. MAG., 1901, p. 534, Pl. XVIII, Fig. 1.

Only this one and the top of what seems to be a second specimen have been seen.

Distribution.—Lower and Middle Devonian.

BELLEROPHON cf. MUNDUS, Whidborne.

See Devonian Fauna, Mon. Pal. Soc., 1892, p. 327, pl. xxxi, fig. 9.

The only example is a fragmentary cast which resembles this species, but it is not mentioned in GEOL. MAG., 1901.

Distribution.—Middle Devonian.

Brachiopoda.

ATHYRIS CONCENTRICA, von Buch, sp.

See Whidborne, GEOL. MAG., 1901, p. 534, Pl. XVIII, Fig. 6.

The example seen is that which was figured by Mr. Whidborne, and is a small rather obscure cast. We have not been able to find the mould mentioned by him as showing the "characteristic strong concentric ridges".

Distribution.—Lower Devonian (Coblencian = France and Germany), Middle Devonian (from base to top), Upper Devonian (Etheridge).

CLORINDA BREVIROSTRIS, Phillips, sp.

The *Pentamerus brevirostris* of authors.

A single example of this species has been detected. It was not mentioned by Whidborne, but was recorded by Davidson from Hope's Nose, near Torquay.

Distribution. — Middle Devonian only (England, France, and Germany).

GYPIDULA GALEATA, Dalman, sp.

Pentamerus galeatus of most authors and of Whidborne in GEOL. MAG., 1901, p. 535, Pl. XVIII, Figs. 4, 5.

This is the prevailing fossil of the bed from which the collection was made. A large number of examples were obtained, most of them being crushed and flattened, sometimes from front to back and sometimes from side to side, but a few occurring in harder ferruginous lumps or concretions preserve much of their original convex character.

Distribution.—Silurian to Middle Devonian.

LEPTÆNA RHOMBOIDALIS, Wilckens, sp.

This species was recorded by Mr. Whidborne and five specimens have been seen.

Distribution.—Silurian to Upper Devonian and Carboniferous.

ORTHIS INTERLINEATA, J. de C. Sowerby.

This species was not recorded by Whidborne and seems to be rare, for only two examples have been seen.

Distribution.—Middle and Upper Devonian (Etheridge).

ORTHOTETES UMBRACULUM, Schlotheim, sp.

Recorded and figured by Whidborne in GEOL. MAG., 1901.

The figured specimen and seven other fragments exist.

This species is regarded by Dr. Ivor Thomas as belonging to his genus *Schellwienella* (*The British Carboniferous Orthotetinæ*: Mem. Geol. Surv. Gt. Britain, 1910, Palæontology, vol. i, pt. ii, p. 97).

Distribution.—Lower to Upper Devonian (Etheridge).

SCHIZOPHORIA STRIATULA, Schlotheim, sp.

Hysterolithus, Linnæus, Museum Tessinianum, 1753, pl. v, figs. 2, *non* figs. 1.
Anomia hysterita, Linn. Syst. Naturæ, 1758, 10th ed., p. 703, *pars*.
Orthis hysterita, Gmelin, in Whidborne, GEOL. MAG., 1901, p. 536.
O. aff. *Monnieri*, Rouault, in Whidborne, op. cit.

Having examined the original figures of Linnæus in his Mus. Tess. I find that figures No. 2 represent internal casts of the form which Schlotheim subsequently called *Terebratulites striatulus*, while figures No. 1 portray a different species, for which the name *hysterita* should be retained. The Torquay specimens are *striatula*.

Distribution.—*Orthis hysterita* is recorded by Kayser from the Lower Devonian of Germany, and this may be the true *hysterita*, but *O. striatula* has not been recorded from the Lower Devonian. On the other hand, it occurs frequently in the Middle and in the Upper Devonian of England, France, and Germany (*teste* Davidson, Haug, and Holzapfel).

SPIRIFER CURVATUS, Schlotheim, sp.

Recognized and figured by Whidborne, GEOL. MAG., 1901.

Several specimens of this species occur, including that figured by Whidborne, but they are all more or less crushed. Two of them are impressions of the outer surface and show the characteristic ornamentation.

Distribution.—Lower and Middle Devonian.

SPIRIFER SPECIOSUS, Schlotheim, sp.

S. costatus, J. de C. Sowerby, Trans. Geol. Soc. Lond., 1840.

Two examples of this species occur, and are probably those which Mr. Whidborne took for *S. primævus*, Steininger. The latter,

however, is a more quadrate form than the Torquay specimens, which agree with casts of *S. speciosus*.

Distribution.—Lower Devonian (Coblencian) and Middle Devonian, but rare above the Eifelian (Calceola Shales).

SPIRIFERINA INSCULPTA, Phillips, sp.

This species was not recorded by Mr. Whidborne, but there are three pieces of slate bearing the number 15 which contain well-preserved fragments of it showing details of the sculpture and also two internal casts which are probably of the same species.

Distribution.—Middle Devonian to Carboniferous.

STROPHEODONTA INTERSTRIALIS, Phillips, sp.

St. nodulosa, Whidborne (*non* Phillips), Dev. Fauna, Mon. Pal. Soc., vol. ii, pl. xvi, figs. 8–10, 1893. Figs. 6 and 7 of the same plate may represent *Leptæna nodulosa* of Phillips, which Davidson has regarded as synonymous with *L. rhomboidalis*.

St. tæniolata, Whidborne (*non* Sandberger), GEOL. MAG., 1901, p. 537, Pl. XVIII, Figs. 8, 9.

The Torquay specimens cannot be identified with the *St. tæniolata* of Sandberger, but they exhibit radial costæ identical with those seen on the shells figured as *St. nodulosa* from the Middle Devonian limestones of Lummaton and Wolborough. This form I regard as only a variety of *St. interstrialis*, Phil., the typical form of which also occurs in the same limestones. Sandberger's *tæniolata* differs from *interstrialis* of Phillips in being of more oval and semicircular contour, in the length and width showing equal measurements, and in its possession of a far greater number of primary costæ.

Distribution.—Middle Devonian only (Etheridge).

Crustacea.

PHACOPS cf. SCHLOTHEIMI, Brown, sp.

A tail (minutely granulated), a head, and other fragments in the matrix belong to a species of *Phacops*. There is also part of another head and a large thorax. The eyes are certainly larger than the typical form of *Ph. latifrons*, and as Mr. Whidborne pointed out they contain eight lenses in a row, whereas *latifrons* has only five or six and *batracheus*, Whidborne, has only four or five. His identification may therefore be retained, but it makes no difference in regard to comparative age, as *Ph. Schlotheimi* is essentially Middle Devonian, occurring both in the Calceola Shales (Eifelian) and in the *Stringocephalus* limestones (Givetian).

The material forwarded from Torquay did not include any specimens which could be identified with *Conocardium cuneatum*, Römer, or *Atrypa reticularis*, of which Mr. Whidborne recorded single examples. [Note by A. J. J.-B.: The material in my hands has again been searched for anything which might be referable to either of these species, but without success.]

Conclusions.

The four fossils identified by Mr. Whidborne with species which were essentially Lower Devonian or Coblencian were those regarded as *Orthoceras hercynicum*, *Spirifer primævus*, *Orthis hysterita*, and

Strophomena tæniolata. From the preceding notes it will be seen that the *Orthoceras* is now identified as *O. speciosum*, Münster (a Middle and Upper Devonian form); that the record of *Spirifer primævus* was probably based on the casts of *S. speciosus*; that the true *Orthis hysterita*, Linn., does not occur, the form in question being the *O. striatula* of Schlotheim. Finally, the species regarded by Mr. Whidborne as *Strophеodonta tæniolata* must be identified with a variety of *St. interstrialis*, Phil., a well-known Middle and Upper Devonian species.

Thus the testimony which seemed to turn the scale in favour of a Lower Devonian age for the fauna has completely vanished, while strong new evidence for its being of Middle Devonian age has been discovered in the recognition of *Anarcestes lateseptatus*, *Orthoceras speciosum*, *Bellerophon mundus*, *Clorinda brevirostris*, *Orthis interlineata*, *Schizophoria striatula*, *Spiriferina insculpta*, and *Strophеodonta interstrialis* (var. *nodulosa*).

The following table shows the range of the species as now identified, and makes it certain that the affinities of the fauna are with the Middle and not with the Lower Devonian. All the species which have been identified with previously known forms occur in the Middle Devonian, either of this country or of Germany, while only seven of them have also been found in the Lower Devonian.

Names.	Silurian.	Lower Devonian (Coblencian).	Middle Devonian (Eifelian).	Upper Devonian.	Carboniferous.
Anarcestes lateseptatus, Beyrich			x		
Orthoceras speciosum, Münster			x	x	
Orthoceras sp.					
Capulus priscus, Goldfuss		x	x		
Bellerophon cf. *mundus*, Whidborne			x		
Athyris concentrica, von Buch		x	x	x	
Clorinda brevirostris, Phillips			x		
Gypidula galeata, Dalman	x	x	x		
Leptæna rhomboidalis, Wilckens	x	x	x	x	x
Orthis interlineata, J. de C. Sowerby			x	x	
Schizophoria striatula, Schlotheim			x	x	
Orthotetes umbraculum, Schlotheim		x	x	x	
Spirifer curvatus, Schlotheim		x	x		
S. speciosus, Schlotheim		x	x		
Spiriferina insculpta, Phillips			x		x
Strophеodonta interstrialis, Phillips			x		
Phacops Schlotheimi, Bronn			x		
Aulacophyllum longhiense, Schlüter			x		
Duncanella cf. *major*, Schlüter			x		
D. cf. *pygmæa*, Schlüter			x		
Cladochonus Schluteri, Holzapfel			x	x	
Pleurodictyum pachyporoides, Whidborne					
Metriophyllum (?)					

VI.—Saturation of Minerals.

By Alexander Scott, M.A., B.Sc.,
Carnegie Research Scholar of the University of Glasgow.

In a recent paper [1] Professor Shand put forward a plea for the more careful consideration, in rock classification, of the saturated or unsaturated state of the constituent minerals. The criterion of saturation which is assumed is the capability of co-existence with some form of free silica, as shown by the "observed facts of distribution". By means of this criterion, the rock-forming minerals are divided into two groups—the saturated minerals and the unsaturated ones. The former group includes the felspars, amphiboles, pyroxenes, micas, and most of the so-called accessory minerals, as well as those of pneumatolytic origin; while the latter group comprises the felspathoids, olivine, the spinels, corundum, and the garnets (except spessartite, which is put into the first class). Rocks are divided into three classes, according as they are made up wholly of saturated minerals, partly of saturated and partly of unsaturated ones, or wholly of unsaturated ones.

The criterion is so obvious that it has been implicitly used, at least in part, in most of the classifications proposed since Zirkel's [2] in 1866. In the American Quantitative Classification, for example, the ratio of felspar to lenad (felspathoid) takes second place only to the ratio of salic to femic minerals in determining the position of a rock.[3] The 'class' is determined by the latter ratio and the 'order' by the former. In practically all cases, however, the application of this idea has not extended beyond the discrimination of the felspar and felspathoid-bearing rocks, and what Professor Shand advocates is the extension of the principle to the other minerals of igneous rocks. There are, however, certain inherent difficulties in such a general application, and it is now proposed to consider, very shortly, some of these difficulties.

The first question which arises is whether the method of determining which minerals are saturated and which are not, is sufficiently exact. The distribution of minerals in igneous rocks, apart from all consideration of the history of the rocks, seems to be rather too empirical to be used as a satisfactory criterion. For example, olivine must be included in the list of unsaturated minerals, and yet it occurs along with quartz in a number of rocks. In addition to those mentioned by Professor Shand, several rhyolites in America [4] and elsewhere [5] contain olivine and tridymite, while the author has described pitchstone-porphyries from Arran [6] containing phenocrysts of olivine and quartz. In the former case the minerals occur in lithophysæ and may have had a hydrothermal origin after the consolidation of the rock, while in the latter the olivine is probably xenocrystic. Quartz-dolerites are usually supposed to have caught up

[1] "On Saturated and Unsaturated Rocks": Geol. Mag., Dec. V, Vol. X, pp. 508–14, 1913.
[2] *Lehrbuch der Petrographie*, Bd. i, p. 450, 1866.
[3] *Quant. Class. of Igneous Rocks*, 1903, p. 123 et seq.
[4] e.g. Iddings, Amer. Journ. Sci., ser. III, vol. xxx, pp. 58–60, 1885.
[5] Iddings & Penfield, ibid., ser. III, vol. xl, pp. 75–8, 1890.
[6] "Pitchstones of South Arran": Trans. Geol. Soc. Glasgow, vol. xv, pp. 19–37, 1913.

siliceous material which remains partly undissolved, while the quartz basalts of California[1] have been explained as due to the intratelluric mixing of a dacite and basalt. This explanation has not been fully accepted,[2] although the presence of a reaction-rim round the quartz crystals indicates their probable xenocrystic origin.

There are two possible ways, however, in which primary quartz (or other silica mineral) may be formed in unsaturated rocks in small quantities. If water be present in a magma consisting mainly of metasilicates, the hydrolitic action of the water vapour or its dissociated constituents at high temperature may cause the metasilicates to partly break up into orthosilicate and free silica, and the latter may finally crystallize as quartz or tridymite.

The other possibility is that the reaction

$$\text{olivine} + \text{silica} \longrightarrow \text{enstatite}$$

may be appreciably reversible. It is most probable that all chemical reactions are theoretically reversible, though, in many cases, under suitable conditions a reaction can proceed so far in one direction that the reverse reaction cannot be detected. Since practically all chemical reactions involve an absorption or evolution of heat, it follows that one of the actions in a reversible reaction is, in general, endothermic and the other exothermic, and we can deduce, thermodynamically, that a rise in temperature displaces the equilibrium position in such a way that the endothermic reaction receives the greater acceleration. The formation of a metasilicate by the interaction of silica and an orthosilicate is exothermic, and the reverse reaction is therefore endothermic and will proceed to a greater extent the higher the temperature. Thus the possibility of silica minerals separating from a part-saturated rock will be greater when the crystallization takes place at a high temperature than when it occurs at a lower one.[3]

The disadvantages of a criterion such as this empirical one of 'saturation', and indeed of all similar empirical ones, become more manifest when the stability relations of the minerals in a rock are considered. So many factors, external and internal, influence the cooling of a rock, that in many cases the resultant solid is not in a condition of maximum stability, and one function of a rational classification should be to indicate in what way, and to what extent, there is deviation from a state of equilibrium. For instance, many rocks show evidence of undercooling, not only with regard to the passage from the liquid to the solid state, but also with regard to transformations in the solid state. Thus glass is not a true solid but merely an undercooled liquid, and, as such, is a metastable phase at ordinary temperatures. Devitrification, i.e. the transformation to the more stable crystalline form, follows, in accordance with the Principle of Maximum Work, the glass having a higher potential than the solid.

[1] Diller, Bull. U.S. Geol. Surv., 1891, No. 79, pp. 21–33.

[2] Cf. Iddings, Bull. U.S. Geol. Surv., 1890, No. 66, pp. 20–32.

[3] Since this was written, Bowen & Andersen (Am. Journ. Sci., ser. IV, xxxvii, pp. 487–500) have described experiments which show that on cooling a melt of the composition MgO–SiO_2, some forsterite separates out first and then the residual liquid crystallizes as a mixture of silica and clinoenstatite.

The comparative rarity of leucite may be explained in a similar way. This mineral seems to form only in a small temperature interval,[1] and if, by undercooling or otherwise, crystallization takes place outside this interval, the final product is a mixture of orthoclase and nepheline. This may also be expressed by saying that the reaction

$$\text{kaliophilite} + \text{orthoclase} \rightleftharpoons \text{leucite}$$

is reversible, and proceeds towards the formation of leucite only through a certain temperature range.

In this case, the effect of undercooling is not merely physical but chemical also, and is therefore analogous to the phenomena observed in the cadmium-antimony alloys.[2] A mixture of equal atomic percentages of cadmium and antimony, cooling from the fused state, deposits crystals of a compound Cd Sb, if the melt is inoculated; otherwise, without inoculation, undercooling takes place and a mixture of antimony and a compound $Cd_3 Sb_2$ separates. The freezing-point curve of the metastable system therefore differs from that obtained under conditions of stable equilibrium. The system albite-(soda)-nepheline is probably similar, save that the compound, analcite, requires the presence of water before it is formed, in addition to definite conditions of temperature and pressure.

Undercooling, however, may take place in the solid state as well as in the liquid state, and involve the presence of unstable or metastable phases. Instances of this phenomenon are common amongst the rock-forming minerals, silica itself being a good example. According to recent work,[3] β-cristobalite is the modification of silica stable above 1,470°; β-tridymite, between 870° and 1,470°; β-quartz between 575° and 870°; and α-quartz below 575°. The occurrence of tridymite in certain effusive rocks, such as the trachyte of Drachenfels, is well known, and it will be obvious from the above that the mineral must be an unstable phase. Its origin may be due to crystallization from the magma at a temperature above the transition-point, and then owing to the rapid cooling, the transformation to quartz may be inhibited. It is possible, however, as Fenner[4] has pointed out, that crystallization may have occurred below 870°, and that an unstable form has developed in accordance with Ostwald's rule, that the most stable phase may not be attained directly, but that phases of intermediate stability may first form. As in the first case, a rapid fall to ordinary temperatures might greatly reduce the velocity of inversion. There are apparent exceptions to Ostwald's rule, but it is possible that these may be explained by the thermodynamic potential of the liquid at the given temperature being lower than, or nearly equal to, the potential of the modifications which fail to appear. In the case of tridymite, quartz, etc., the change is apparently physical and is confined to a polymorphic transformation.

The hornblendes and pyroxenes may constitute another example of the same type. While there is still some obscurity regarding the

[1] Cf. Washington, Journ. Geol., xv, pp. 257–79, 357–95, 1907.

[2] Kurnakov & Konstantinov, Zeit. anorg. Chem., lviii, pp. 12–22, 1908.

[3] Fenner, "The Stability Relations of the Silica Minerals": Amer. Journ. Sci., ser. IV, xxxvi, pp. 331–84, 1913.

[4] Fenner, loc. cit., p. 342.

relations of these two groups, the evidence both of petrography and of synthetic work[1] is in favour of pyroxene being the high temperature form and hornblende the low temperature one. In the diorites and gabbros, hornblende often appears as a parallel growth on pyroxene, and many cases have been described of the former mineral containing cores of the latter.[2] Similarly augite is often found pseudomorphed by hornblende. It has been argued against this view that the hornblende, and the pyroxene from which it forms, have different compositions, particularly where the alteration has been aided by pressure, as in the formation of hornblende schist by the alteration of a dolerite.[3] This difference, however, is probably due to the fact that these minerals are capable of combining many molecules in solid solution, and that this capability varies with the conditions of crystallization. Thus, at Garabal Hill,[4] the margin of an intrusion is a hornblende diorite with about 30 per cent of hornblende, and the centre, a few feet distant, is a hornblendite with 85 per cent of hornblende, while the composition of the two rocks is approximately the same. The cases of alteration of hornblende into pyroxene would seem to be explained by reheating due to later intrusions,[5] or to some similar cause.

Another change which may take place in the solid state is the breaking up of a solid solution on cooling. Vogt[6] describes the separation of augite from solid solution in enstatite and also ascribes this origin to some perthitic growths.[7]

So far, only the effect of temperature on the formation of stable minerals has been considered. The conditions of pressure, however, also exert a considerable influence, particularly in many plutonic rocks. When an igneous rock contains minerals which are generally of metamorphic origin, it is assumed that these have formed under pressure. For example, garnet is a typical product of metamorphism, and when it does occur in a plutonic rock it has probably crystallized under high pressure. In the case of the Charnockite Series, the garnet seems to have originated in this way, as there is other evidence of the rocks having undergone dynamic action,[8] while the eclogites in many cases show similar effects.[9] Fermor[10] postulates for the formation of kodurite, an infra-plutonic zone of garnet-bearing rock.

The evidence of synthetic work is likewise in favour of garnet forming only under particular conditions of pressure and probably

[1] Allen, Wright, & Clement, Amer. Journ. Sci., ser. IV, xxii, pp. 385–438, 1906; Allen & White, ibid., ser. IV, xxvii, pp. 1–47, 1909; Doelter, *Neues Jahrbuch*, 1897, pt. i, pp. 1–26.

[2] Cf., for example, Allport, Q.J.G.S., xxxv, pp. 637–42, 1879; Wyllie and Scott, GEOL. MAG., Dec. V, Vol. X, pp. 499–508, 536–45, 1913.

[3] Teall, Q.J.G.S., xli, pp. 133–44, 1885; see also Harrington, Rec. of Progress. Geol. Surv. Canada, 1877–8, p. 21 G.

[4] Wyllie & Scott, loc. cit.

[5] Cf. Lacroix, *Minéralogie de la France*, i, pp. 668–9, 1895.

[6] Q.J.G.S., lxv, pp. 100–1, 1909.

[7] Tscher. Min. u. Pet. Mitt., xxiv, pp. 537–42, 1905.

[8] Holland, Mem. Geol. Surv. India, xxviii, pp. 117–249, 1898.

[9] Cf. Hezner, Tscher. Min. u. Pet. Mitt., xxii, pp. 437–505, 1903, for origin of eclogites.

[10] Rec. Geol. Surv. India, xlii, pp. 208–30, 1912; xliii, pp. 41–7, 1913.

in a narrow temperature range. Numerous observers[1] have reported that garnet, on fusion, breaks up and finally recrystallizes as a mixture of other minerals such as anorthite, monticellite, melilite, etc. Attempts to synthesize garnet have not met with much success, though the formation of the mineral has been reported in a few cases.[2] Hence we may assume that if a rock containing garnet had crystallized by a normal cooling process, under ordinary pressures, garnet would be entirely replaced by other minerals. In some cases it is probable that some of the minerals did not form under such high pressure as the garnet, and hence the latter would be liable to undergo resorption by the residual liquid magma. The well-known celyphite border which occurs round pyrope crystals in peridotites may arise in this way by the action of a liquid residual magma on the pyrope, under pressures much lower than those at which the latter form and therefore under conditions which would render pyrope an unstable phase.

Thus it will be seen that there are grave objections to the garnets being considered as saturated or unsaturated in the way felspar or nepheline might be. If spessartite be considered as saturated merely on account of its co-existence with quartz in certain rocks, and the other garnets as unsaturated on account of the absence of this property, the result would be, not only to divide closely related garnet rocks into two widely different groups but also probably to class each with rocks from which they might differ considerably both in chemical and mineralogical composition. The conclusions of Boeke[3] render it very improbable that spessartite differs essentially from the other garnets, as he finds that almandine forms a continuous series of solid solutions, with both spessartite and pyrope, and that grossularite and andradite form a similar series. The two latter, however, form with each of the others systems which conform to Roozeboom's fifth type, as does also the system pyrope-spessartite, two limited series of solid solution being formed. Any differences which do exist, are likely to occur between those minerals which give systems of the latter type, but such differences, if any, would probably be physical. Similar objections exist with regard to the micas, which also seem to form generally under particular conditions of pressure and temperature.

Although the hornblendes and pyroxenes are found along with quartz, it is probable that the members of these groups which contain the sesquioxides—alumina and ferric oxide—can react with free silica under certain conditions. The most generally accepted explanation of the presence of these oxides is that they occur in molecules of the type $R''Al_2SiO_6$ (Tschermak's silicate), where R is ferrous iron or magnesium, which molecules are obviously unsaturated with respect to silica. Harker[4] explains certain phenomena of differentiation as due to a reaction taking place between diopside and

[1] Bourgeois, Annales Chim. Phys., ser. v, xxix, p. 458, 1883; Vogt, *Mineralbildung in Schmelzmassen*, 1892, pp. 186–8, etc.

[2] Gorgeu, Annales Chim. Phys., ser. vi, iv, pp. 536–53, 1885.

[3] Boeke, *Zeit. Kryst. Min.*, liii, pp. 149–57, 1913.

[4] *Geol. Small Isles* (Mem. Geol. Surv. Scotland), 1907, p. 91.

Tschermak's silicate with the production of olivine and anorthite. Again, minerals such as tourmaline and topaz are usually the result of pneumatolytic or fumarolic action, and as such it is impossible to deduce from their co-existence with silica in rocks that they would form during the normal cooling of an 'acid' magma.

From what has been said above it is obvious that a classification of igneous rocks can no longer be made dependent on such a factor as saturation with respect to silica, particularly when applied in this empirical fashion. During the period of cooling, rocks are subjected to many vagaries, owing to the impossibility of the external conditions being uniform, and any classification dependent on the final mineralogical composition without reference to the 'cooling-history' is not of much use. Any group of igneous rocks must be subdivided according to the method of development of the particular rocks, and it is impossible to compare directly on a purely modal basis a rock which has formed through a normal cooling process and is therefore in a state of equilibrium and one which is not in equilibrium owing to such causes as undercooling, inhibition of transformation either in the liquid or solid states, or the formation of some or all of the constituent minerals under abnormal conditions of pressure and temperature. In rocks of similar composition, the minerals which develop in the latter case are often widely different from those arising in the former one, and hence such minerals as the garnets, topaz, etc., cannot be said to be 'saturated' or 'unsaturated' in the sense that albite, nepheline, or leucite can be. Similar objections exist with regard to a classification on a basis of the chemical composition or of the 'norm' derived from it, and one of the chief advantages of the American system is that it provides an extremely good method of indexing the increasing volume of rock analyses.

These two factors, however, the chemical and mineralogical composition, are the only ones we have for a basis in classification, but they must be correlated in such a way that as much information as possible is obtained regarding the 'cooling-history' of the rocks. The crystallization of rocks can no longer be considered either as wholly fortuitous, or as wholly the result of a normal cooling process, but as the result of the operations of the laws of physical chemistry. Hence the objects of a rock classification must be to correlate rocks not only of similar chemical composition but also with similar 'cooling-histories'.

The data for this can be derived from (*a*) the determination of chemical composition, (*b*) of mineralogical composition, (*c*) the field relations of the rocks, (*d*) the evidence of synthetic work in mineralogy. The defects of most of the current classifications can be traced to the position of paramount importance given to some one of these bases and to the subordinate positions assigned to the others. The occurrence of minerals in rocks, as shown by the 'observed' facts of distribution, must be correlated with the other evidence—particularly that of field relations and of synthetic work — concerning the conditions of equilibrium both during the cooling process and in the solid phases observed in the rock. It is only in this way that we can acquire a knowledge of the genetic relationships and the general history of igneous rocks.

REVIEWS.

I.—Fossil Crustacea.

1. E. Stolley. Ueber zwei neue Isopoden aus nord-deutschen Mesozoikum. 3 Jahresber. d. niedersächsischen geol. Ver. zu Hannover, 1910 [? 1913], pp. 191–216, Taf. vi.
2. Ph. C. Bill. Ueber Crustaceen aus dem Voltziensandstein des Elsasses. Mitth. d. geol. Landesanstalt von Elsass-Lothringen, Bd. viii, Hft. iii, pp. 289–338, Taf. x–xvi, 1914.

1. Fossil remains of Isopoda are so rare and so little known that considerable interest attaches to Herr Stolley's detailed description of two new species, *Palæga jurassica* from the Middle Jurassic (Dogger) near Harzburg, and *Urda cretacea* from the Middle Gault of Hannover. The genus *Palæga* has not hitherto been recognized earlier than the Cenomanian, but the author very justly points out that the name covers an assemblage of more or less incompletely known forms which may not be strictly congeneric. It may be added there is very little reason for supposing that any of these forms belong to the family Ægidæ in the sense in which it is understood by modern zoologists, and that the presence of ocelli on the dorsal surface of the head in the new species, if it were confirmed, would be a character of far more than the trifling importance which the author attributes to it. The second species, *Urda cretacea*, is referred to a genus hitherto known only from the Kimmeridgian of Solenhofen, and is described from a specimen in which the segmentation of the body is more perfectly preserved than in the case of the earlier forms. No new light, however, is thrown upon the affinities of the genus. Here, as elsewhere, it seems possible that something might result from a more extended comparison with recent forms.

2. Herr Bill has had the good fortune to discover, in the Upper Bunter of Alsace, a Crustacean fauna hitherto practically unknown, although one or two forms were very incompletely described long ago by H. von Meyer and others. Three of the new species are referred to the Decapoda, and are of special interest as being among the very earliest forms that can with certainty be attributed to that order. The new genus *Clytiopsis*, in which two of the species are placed, belongs to the tribe Nephropsidea, which includes the recent Lobsters and Crayfishes, and of which the oldest representative has hitherto been the Liassic *Eryma*. The material was sufficiently well preserved to enable the structure not only of the body but also of a good many of the appendages to be described with considerable detail. The third Decapod is one of the Penæidea, and is referred, provisionally, to the genus *Penæus*.

A new genus *Schimperella*, with two species, is based on some finely preserved material which has rendered possible a fairly complete account of its structure. It is referred to the 'Schizopoden', by which name, apparently, the author means only the Mysidacea. It seems highly probable, although no brood-pouch has been detected, that *Schimperella* really does belong to this order, of which no representatives have hitherto been discovered to link the Carboniferous forms with those now existing.

The other Crustacea described in this memoir are of less general interest. *Triasocaris* is established as a new genus, and is included in the Syncarida with an expression of doubt that seems to be quite justified. A preoccupied name, *Diaphanosoma*, has been chosen for another new genus, based on what the author thinks may be a larval form of one of the Decapods. An *Estheria* is described which, by a rare exception, shows traces of the body and some of the limbs. Finally, *Limulites Bronni* is redescribed, and a misprint in Schimper's original account is corrected, thereby reducing to one-tenth the measurements which had led subsequent writers to attribute to this species the relatively gigantic total length of 1½ metres.

W. T. Calman.

II.—Geology of the Province of Yünnan in Western China.

During the years 1907–10 several traverses were made by J. Coggin Brown, M.Sc., between Bhamo and Têng-yüeh in the province of Yünnan, the results of which are described in a series of short papers.[1]

The greater part of the area is occupied by a series of gneisses, mica-schists, and crystalline limestones with some intrusive granites. At one locality there is a small development of quartzites and phyllites probably belonging to the Kao-liang Series of Upper Burma. Farther to the east rocks of Ordovician and Silurian age occur. The fossils from these beds have been identified provisionally by F. R. Cowper Reed, M.A.

In the neighbourhood of Têng-yüeh there are four groups of extinct volcanoes. The rocks extruded from these volcanoes are described by R. C. Burton, B.Sc. They belong to three periods: (1) older bedded pyroxene-andesites; (2) massive augite-andesites, some of which are olivine-bearing and grade into olivine-basalts; with these are associated some augite-enstatite-andesites and hornblende-andesites containing nepheline; (3) olivine-basalts. The last stages of vulcanicity are represented by groups of hot springs. The volcanic rocks are probably of late Tertiary age.

Mr. Burton notes that these volcanoes lie on the line joining Barren Island, Narcondam, and Mount Popa (Burma) with Loi-han-hun in the Northern Shan States. This line is itself a continuation of the Sunda volcanic chain running through Java and Sumatra. The rocks extruded by volcanoes along this line are petrographically similar, consisting of augite-andesites, some hornblende-andesites, and olivine-basalts. The presence of nepheline in some of the rocks of Yünnan is interesting, but it appears to be a rare constituent, and its presence in such quantities cannot, as Mr. Burton thinks, be regarded as placing these rocks in the alkali series, nor need it indicate the proximity of an "Atlantic province". It is interesting to note that in Yünnan, as at so many other centres of vulcanicity, the last lavas to be extruded are olivine-basalts.

In some parts of the area, notably in the plains of Kan-ngai and Nan-tien, there are extensive lacustrine deposits; these are partly of late Tertiary age, but in places deposition is still going on.

[1] Records of the Geological Survey of India, vol. xliii, 1913, pp. 173, 206, 327.

Some interesting changes in the course of the Irrawaddy near Bhamo are noted. These are apparently due to the cutting back of tributaries, assisted by great differential earth-movements.

These papers are illustrated by thirteen plates and one geological map on a scale of 4 miles to the inch.

III.—Petrographical Provinces and the Sequence of Types.

SOME very important criticisms of the wider generalizations of modern petrology were made by Henry S. Washington in a paper read before the International Geological Congress in 1913 on "Volcanic Cycles in Sardinia".

The Sardinian volcanoes belong to three different volcanic cycles. A careful study of the sequence of the various lava-flows brings out the following points. The sequence as a whole is discontinuous but recurrent. The close of one magmatic cycle is simultaneous with the ending of one volcanic phase, and the recurrence of a new one coincides with a change in the intensity or character of the vulcanicity. In the several successive cycles there is a progressive decrease in differentiation; thus the earliest cycle comprises rhyolites, trachytes, andesites, and basalts; while in the latest felspar-basalts are the only lavas which have been extruded. Each cycle closes with the extrusion of felspar-basalt. The sequence here observed is not in accordance with the 'law' of divergence from an average magma. Harker would, however, regard such exceptions as due to the suppression of one of two divergent lines.

The author points out that the sequence must depend on such factors as the form of the magma basin, the point at which this is tapped, and the character and amount of the volatile constituents which escape, so that it may be questioned whether the sequence of types really possesses the great importance usually attributed to it. For most volcanic regions it appears that the sequence of types varies somewhat with the character of the regional magma, but nearly always closes with basaltic rocks. The coincidence of the several cycles with discontinuity of volcanic activity, which is so well shown in Sardinia, is also observed at Pantelleria and in many other areas of vulcanicity; on the other hand, there are cases, as at Santorin, where lavas extruded at different periods are practically identical in composition.

The lavas of Sardinia furnish another of the now numerous instances of the association in the same volcano of the so-called 'Atlantic' and 'Pacific' types. It seems impossible to refer all rock types to only two lines of variation. The concentration of a very large number of rock analyses round several types indicates that there has been one general earth-magma. The magmas which characterize different petrographical provinces must have been derived from this general magma by differentiation *in all possible directions*. Attention must be paid to magnesic, ferrous, and potassic magmas, and not only to sodic ones. At present far too much importance is attached to the occurrence of such minerals as ægirite and nephelite, even when present in quite small amount, while the presence, for instance, of potash in biotite is often neglected.

The data at present available are insufficient for even the broadest generalizations. Petrologists must recognize the need of quantitative data, of adequate chemical analyses, and of the complete collection of data in the field. Only thus can they hope for the successful application of the principles of physical-chemistry to the solution of the complex problems of petrology.

IV.—Bulletin of the Seismological Society of America.

IN the issue for March, 1914 (vol. iv, No. 1), a useful epitome of the seismological work of John Milne is given by Comte de Montessus de Ballore.[1]

A brief historical account of Milne's life-work, in which it is pointed out that he was always a decided partisan of the tectonic or geologic origin of earthquakes, forms an introduction to an admirably arranged bibliography of Milne's papers. The fourteen heads under which the references are grouped greatly facilitate the selection of those which deal with any particular branch of the subject of seismology, and in every case notes, giving a general idea of the contents, are appended to those of most importance.

Under separate headings we find a record of papers on geographical and geological points of view, volcanoes, internal heat and state of the globe, and other aspects of the subject.

This analysis of Milne's work should prove valuable to all who are interested in any of the numerous branches of seismological investigation.

V.—The Cotteswold Naturalists' Field Club.

The Proceedings for December 1913, being pt. ii of vol. xviii, contain a record of the excursions and meetings of this Club during 1913. Visits were paid to Tidenham Chase and Tintern, the Sherborne district of Dorset, Wotton-under-Edge, and other interesting localities. Mr. L. Richardson contributes a geological map, on the 6 in. scale, of the southern part of Cheltenham and the adjoining country, which shows the distribution of both the superficial and solid rocks. The unusual colour-scheme adopted is somewhat confusing, although in other respects the map is quite clear. Twelve pages of text are given in explanation of the sheet. A map of the northern part of Cheltenham, with explanation, was published in pt. iii, vol. xvii, of the Proceedings of the Club. Professor Lapworth discusses the origin of the boulders collected in the grounds of Bournville, Birmingham, and gives a brief sketch of the glaciology of the Midlands. An account of the water supply of Cirencester is given by T. Hibbert and L. Richardson; the latter also records the details of a deep boring at Kemble passing through 353 feet of strata from Great Oolite to Upper Lias.

[1] A life of Professor John Milne, F.R.S., with his portrait and a list of his published works, appeared in the Geol. Mag. for August, 1912, pp. 337–46; his death was recorded (July 31, 1913) in the Geol. Mag., September, 1913, p. 432.

VI.—Brief Notices.

1. New Periodical.—The first volume of the Mémoires de l'Institut Géologique de l'Université de Louvain, published under the editorship of Henry de Dorlodot, has recently appeared. A quarto, printed in large type and well illustrated, it makes an imposing volume. It contains three papers: Asselbergs, "Le Dévonien inférieur du Sud-Est de l'Ardenne Belge"; Salée, "La groupe des Clisiophyllides"; and Wong Wen-Hao, "La Porphyrite quartzifère de Lessines." Other volumes will appear according to material in hand.

2. Triassic Fauna of India.—Diener has published in *Palæontologia Indica* (n.s., vol. v, No. 1, 1913) a memoir on the Triassic Faunæ [*sic*] of Kashmir found by Middlemiss in 1908 and 1909. This fills up a gap in the Indian series, and provides many additional forms for comparison and study. A full description of the stratigraphy was given by Middlemiss in his memoir on the Silurian-Trias of Kashmir in the Records Geol. Surv. India, vol. xl, 1910.

3. New Zealand.—The geology of the Aroha subdivision of Hauraki, New Zealand, forcibly brings to notice how much detailed work remains yet to be done before we can form definite maps of the country. This is a large quarto by Messrs. J. Henderson and J. A. Bartrum, and forms No. 16 Bull. N.Z. Dept. of Mines, Geol. Surv. Branch, 1913. Dealing with Climate, Flora, Fauna, Population, Industries, and Geography as well as Rainfall, this memoir though called geological is quite comprehensive in its view. Previous literature is carefully listed and the views of previous writers properly attended to, and the authors throw the whole of the sedimentary rocks into Jura-Trias with the exception of the various 'Recent Deposits'. The large series of Andesites, Dacites, and Rhyolites are described, and much attention is naturally paid to the mining portion of the area. A chapter on Economics closes the Bulletin, which is accompanied with several clearly printed geological maps.

4. Florida and other Coral-reef Tracts.—Dr. T. W. Vaughan having worked for some years on the Floridian Plateau and included in his observation the Bahamas, Marquesas, and Tortugas has issued in the Journ. Washington Acad. Sci., vol. iv, 1914, a "Sketch of the Geological History of the Florida Coral-reef Tract and Comparisons with other Coral-reef Areas". He seems to believe that the final subsidence occurred after uplift following the close of the Pliocene, and notes that Pleistocene terraces rise to 600 feet in Cuba and 1,000 feet in Barbadoes. The Pleistocene barrier reef on Key Vaca showed 105 feet by boring.

5. Mud Lumps.—So far as is known the 'mud lumps' of the Mississippi delta are peculiar to that river. The name of 'mud lump' has been applied to large swellings or upheavals of tough bluish-grey clay in the territory within a mile or two of each of the mouths of the Mississippi. Many of these mud lumps rise just offshore and form islands having a surface extent of an acre or more and a height of 5 or 10 feet, but some do not reach the water surface. They rise and subside at irregular rates, some suddenly, and constant vigilance is necessary to keep charts of

these waters properly corrected. Mr. E. W. Shaw has spent some time studying these features, and the result of his work will be found in Professional Paper 85 B, Dept. Interior, United States Geological Survey, 1913. At most this paper professes to be a brief summary, but the author's observation lead him to state "the facts that the mud lumps are by far the thickest bodies of clay found in the Delta and that the clay is overlain and underlain by materials similar to those found elsewhere throughout the lower end of the Delta suggest that they are produced by a squeezing of the soft layers and an accumulation of clay from such layers in places where the pressure is less strong, and that the lumps are not upheaved by any such force as volcanism or by pressure from the accumulation of salt, sulphur, or gas below the surface".

6. New York State.—So many scattered papers have appeared on the geology of parts of New York State that it is a boon to find that William J. Miller has thrown the whole into a comprehensive and readable general account, clearly written and admirably supplied with maps and illustrations. The 130 pages are divided into Introduction, Physiographic Provinces, Structure and Drainage, Pre-Cambric, Palæozoic, Mesozoic and Cainozoic History, Appendix, and Bibliography. It forms Bull. 168 of the New York State Museum, 1913 (1914), and is issued at 40 cents.

7. Saratoga Springs.—In 1912 J. F. Kemp wrote a report on the springs themselves, and now Messrs. Cushing and Ruedemann have issued a memoir on the district. The rocks are Pre-Cambrian, Cambrian, Ordovician, and Pleistocene (Glacial), and a general description with lists of fossils is given. Several plates show that remarkable Cambrian structure known as *Cryptozoon proliferum* first described by James Hall. The relation of the geology of the area to Burgoyne's campaign forms an interesting, if unusual, chapter in a geological memoir.

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 13, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President mentioned that, on the proposition of Mr. R. H. Tiddeman, President of the Yorkshire Geological Society, a conference would be held in Leeds next autumn to discuss thoroughly the Glacial phenomena of the North of England.

Mr. John Parkinson exhibited (*a*) a few specimens of the old lacustrine beds from the neighbourhood of Lake Magadi, on the borders of British and German East Africa; and (*b*) specimens of soda and silica from the lake itself. The former consist of unconsolidated ash, fine silts with *Planorbis*, and diatomite. These beds in places are probably over 100 feet thick. With the soda is associated silica, which fringes some fault-scarps and forms narrow ridges in the lake itself.

The following communications were read:—

1. "The Scandinavian Drift of the Durham Coast, and the General Glaciology of South-East Durham." By Charles Taylor Trechmann, B.Sc., F.G.S.

The present communication summarizes observations carried out for some time on the superficial deposits of South-East Durham and the lower Tees Valley. It practically embraces the area represented on the two Geological Survey 1 in. Drift maps, Sheet 103 N.E. (New Series 27) and Sheet 103 S.E. Evidence relating to the pre-Glacial levels and contours of the land in the Permian and Triassic areas has been collected and examined. This supports the conclusion that, immediately prior to the oncoming of glacial conditions. the land stood at not less than 100 feet above its present level.

The fissures and depressions of the Middle and Upper Magnesian Limestones on the eastern side of the Shell Limestone reef have been instrumental in preserving relics of the material brought by the earliest ice-sheet which invaded the district from the North Sea. This material proves to be absolutely devoid of the ordinary glacial erratics of the North of England and Scotland, found in the overlying main Drifts. Several narrow vertical fissures are filled with masses of red sandstone, red, grey, and green marl, peat and masses of peaty wood, and Magnesian Limestone, both of immediately local occurrence and of material strange to the district.

The Scandinavian Drift proper occurs about midway between Hartlepool and Seaham Harbour, and occupies a position near the middle of the stretch of coastline where the red fissures are seen. It has been preserved in a pre-Glacial depression and fissure in the underlying Magnesian Limestone, extending over slightly under a quarter of a mile. It is represented by a transported shelly clay containing a fauna of Arctic affinities, which recalls that of some of the basement clays of Flamborough and Holderness. Among other erratics, a big boulder of titaniferous syenite was found resting immediately upon the Magnesian Limestone near the southern end of this section; special notice was taken also of a very big laurvigite-syenite (5 feet long) and two rather smaller rhomb-porphyries lying on the shore opposite this place.

All the stones (between 300 and 400 specimens) found in this clay were collected and examined. The greater part of them are well-glaciated crystalline rocks, many of which (the typical Christiania eruptives) certainly are, and the greater part may be, of South Norwegian origin. Permian limestone, red sandstone, Chalk, and splintered flints also occur.

The apparent absence of any East Scandinavian rocks in Durham is noticed, and an explanation offered. The early retreat of the Scandinavian ice from the Durham coast, as also its relation to the English and Scottish glaciation, is discussed.

Later than the fissure-filling material are certain water-deposited gravels and sands, which occupy shallow depressions underlying the main Drift seen on the coast. They are noticeable for containing

a rather large proportion of gneissic and schistose rocks, olivine-basalts, etc., in this case presumably of Scottish origin. A comparison with a similar bed on the Northumbrian coast, studied by Dr. J. A. Smyth, is made.

The main Drifts of South-East Durham are briefly described, more especially in relation to the limits and direction of flow of that part of the ice-stream which carried Cheviot material in the last phase of the maximum glaciation of the east coast. The direct southerly or south-westerly movement of this ice towards the northern face of the Cleveland Hills at this period is indicated by striæ, by the western limits of Cheviot material in this area and in Northumberland, and by the superficial mingling in the lower Tees Valley of the products of this ice with material brought at an earlier period over Stainmoor.

The occurrence of Shap Granite and olivine-basalt erratics is indicated on an accompanying map.

The conspicuous kaimes developed about the village of Sheraton and others, associated with the Cheviot Drift, are described. A few remarks are added on a deserted watercourse at Ferryhill, and on the question of post-Glacial erosion.

2. "On the Relationship of the Vredefort Granite to the Witwatersrand System." By Frederick Willoughby Penny, B.Sc., F.G.S.

The Vredefort Granite has always been considered as a member of that 'old granite' group, which everywhere in the Transvaal and in the Orange Free State is found emerging from beneath the Witwatersrand Series.

The relationship of this 'old granite' group to the overlying rocks has been the theme of frequent discussion. The Vredefort area was made the subject of a paper in 1903 by Dr. G. A. F. Molengraaff, who proved to his own satisfaction the intrusive nature of the granite into the encircling sediments. In the following year, however, when work in other areas indicated the probability that there the 'old granite' group formed the floor on which the Witwatersrand Beds were laid down, Dr. Molengraaff practically withdrew his previous deductions regarding the Vredefort area.

In the present paper evidence is brought forward to prove clearly the intrusive character of the Vredefort Granite, not only into the Witwatersrand Beds, but also into the basic intrusion associated with them, based on an examination of the adjacent rocks and a detailed map of several miles along its contact on the north-east side of the granitic boss in the Orange Free State. It is shown that along its margin the granite has removed, possibly by absorption, but more probably by 'underhand stoping', varying amounts of the sediments from point to point; that it has reacted with the basic intrusions in the sedimentary beds, with the consequent production of hybrid rocks; that, in one place, a subsidiary intrusion of granite occurs in the middle of the diabase; and, finally, that the granite, where it comes into contact with the slate members of the Witwatersrand Series, has induced a definite type of metamorphism

in them, producing a magnetite-actinolite-staurolite rock, which is of an entirely distinct type from that induced by the basic intrusion associated with the Witwatersrand Beds, a micaceous phyllitic rock. It is suggested that the Vredefort Granite, instead of being 'Archæan', is of a post-Pretoria – pre-Karroo age, if not contemporaneous with, at least connected with, the same epoch of igneous activity as the 'Red Granite' of the Northern Transvaal.

May 27, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read :—

1. "On the Development of *Tragophylloceras loscombi* (Sow.)." By Leonard Frank Spath, B.Sc., F.G.S.

During his investigation of the Charmouth Lias Mr. W. D. Lang has carefully collected abundant fossil material with reference to its exact stratigraphical horizon, and the author is indebted to him for permission to study the Ammonites. In the material, *Tragophylloceras loscombi* (Sow.) is represented by hundreds of specimens (chiefly young), and a study of the ontogeny of this interesting Ammonite forms the basis of the paper.

A considerable number of specimens were dissected back to the initial chamber or protoconch, and their development was traced in detail. Horizon and history (notably previous interpretations and generic vicissitudes) are also discussed, tables of measurements are given, and the other species of the genus [especially the pre-*ibex Tragophylloceras numismale* (Quenst.), which had long been confused with the post-*ibex Tr. loscombi* (Sow.)] are reviewed.

The evolution of the suture-line was worked out in great detail, and one of the most important points brought out was the demonstration of a simple *Psiloceras*-like suture-line persisting to a late and post-constricted stage. The speculations regarding the bearing of all the important facts upon the phylogeny of the genus *Tragophylloceras*, and upon the connexion of the latter with allied lineages, will prove, it is hoped, of general interest. The development of the suture-line in *Psiloceras* and *Rhacophyllites* is given for comparison.

Since *Tragophylloceras* has morphic equivalents in *Rhacophyllites*, as well as in *Analytoceras*, but, by its suture, is more nearly related to *Euphyllites* and the Psiloceratidæ, it is argued that it can more naturally be attached to those *Mojsvarites* descendants that Professor Diener would group in the Pleuracanthitidæ rather than to the typical Phylloceratinæ.

The pre-Triassic ancestors of the Monophyllitinæ are also reviewed, and a new classification of the family Phylloceratidæ is proposed.

2. "The Sequence of Lavas at the North Head, Otago Harbour, Dunedin (New Zealand)." By Professor Patrick Marshall, M.A., D.Sc., F.G.S.

The North Head of Otago Harbour is situated 13 miles north-east of Dunedin, and forms a more or less precipitous cliff ranging from 300 to 530 feet in height. This cliff presents a remarkably clear

section of a succession of lava-flows, including trachyte, trachytoid phonolites, kaiwekites, trachydolerites, and basalts. It appears that all the lavas were erupted from the same vent, although the surface features do not indicate the point from which they were extruded. Each sheet is covered by a bed of scoria, the general coarseness of which proves that the centre of volcanic activity was not far distant. The author gives a detailed account of the succession of twenty-five flows and the field relations, which leaves no doubt as to the order of extrusion; but the main portion of the paper deals with the petrography of the lavas. The lowest lava is a trachyte composed entirely of anorthoclase-felspar, and is succeeded by a phonolite in which sanidine is the most conspicuous mineral. This is followed by a series of ten basalts of moderately basic character. The next flow is a kaiwekite, a lava of entirely different type, in which a hornblende allied to barkevikite forms the largest crystals. It also contains titaniferous augite bordered with ægirine, and phenocrysts of labradorite and anorthoclase. The lava above contains no phenocrysts, the pyroxene is ægirine, the hornblende is ænigmatite, and there is an abundance of nepheline. Then follows a series of basalts, including two flows of trachydolerite. The lower trachydolerite contains large phenocrysts of nepheline and sodalite, with only a little felspar in the ground-mass. The basalts are succeeded by a phonolite which contains a few phenocrysts of anorthoclase.

The author then discusses the chemical composition and classification of the lavas. He points out that in the lowest trachyte lime and magnesia are practically absent, but that the second lava (phonolite), although still deficient in these constituents, shows a distinct advance. The basalts as a whole are low in magnesia and above the average in alkalies. In the kaiwekite the alkalies advance very considerably, and there is a corresponding increase in silica and decrease in lime and magnesia, features which are still more marked in the succeeding phonolite. He regards the kaiwekite as a connecting link between the basalts below and the phonolite above. The higher basalts are in general somewhat richer in alumina and poorer in lime than those which occur lower in the section.

The lower trachydolerite compares chemically with the kaiwekite, but the presence of nepheline makes it somewhat richer in soda and alumina, and relatively poorer in silica. The final phonolite compares closely with that near the bottom of the section, but is less alkaline than that near the middle of the series.

The majority of the rocks fall into well-known and readily recognized groups. The lowest lava is a trachyte which may be regarded as the effusive representative of a bostonite. The lowest and highest phonolites, being poor in nepheline, are of the trachytoid type, but the central phonolite is almost a nephelinite in character. The basalts are more or less of the normal type and call for no special comment, but the affinities of the kaiwekite and the trachydolerites are discussed in some detail.

The author considers that the porphyritic rocks of intermediate composition, such as the kaiwekites and trachydolerites, may have formed from an undifferentiated magma, a consideration that requires

a threefold eruption from a deep source to an intermediate level. In this case, after a partial eruption of the magma at this intermediate level, complete resorption of the barkevikite and some other minerals would take place, and the residue would differentiate under the forces of gravity into two portions. An upper portion would give rise to the dense non-porphyritic phonolites, and the lower portion would provide the basalts.

The chemical composition of the intermediate lavas, as well as their mineral composition, would suggest that the original magma was that of essexite. It is important to note that in the Island of Tahiti, where there is a similar assemblage of alkaline and basic lavas, the reservoir has been laid bare by denudation and contains essexite as the dominant rock.

OBITUARY.

Dr. ALFRED ERNEST BARLOW,

M.A., D.Sc., F.R.S.Can., F.G.S.A., etc.

Born 1861. Died May 29, 1914.

Amongst the terrible loss of life in the St. Lawrence disaster by the sinking of the *Empress of Ireland*, there comes as a shock to all geologists and mining men interested in the occurrence of ore-deposits in the Archæan crystalline rocks of Canada the loss of one who, for the past thirty years, has taken a most active part in the deciphering of the structure of the earth's crust in the great crystalline areas of North America.

In Dr. Barlow Canada had the last court of appeal on the genesis of its ore-deposits. Trained first at home in Montreal by his father, Robert Barlow, geologist and cartographer under Sir William Logan, of the Geological Survey of Canada, Barlow studied at McGill University under Sir William Dawson, Dr. Harrington, and other geologists, and was asked to join the technical staff of the Geological Survey of Canada in 1883, at Ottawa, under Dr. A. R. C. Selwyn. Filled with energy and enthusiasm for the science of geology, he entered the field in the province of Quebec, and later on wrought hard in the nickel and copper-bearing deposits of the Sudbury region in Ontario. His work in the area under question is a monograph of the greatest value, and his reports and papers regarding the genesis of the nickeliferous pyrrhotite of the region, and the occurrence of the same in the various types of crystalline rocks developed during the magmatic differentiation which took place are recognized as the best and most natural and practical treatises. In the Cobalt silver-mining district of Ontario, throughout the Lake Temiskaming areas of crystalline rocks, in the iron-ore region of Lake Timagami, as well as in the gold-bearing rocks of the Porcupine District, on the Montreal River, and in the Haliburton and Bancroft region of Southern Ontario, throughout the Hastings Series, besides the special district of Dungannon (where corundum deposits are found), Dr. Barlow was *the* worker who, with unceasing energy and devotion to the

solution of the difficult problems presented in these various fields, characterizing nearly as many petrographical provinces, has left a record of noteworthy achievement to our science. His writings are numerous and important. Fearless in all his endeavours to ascertain the truth, he published the same, as it presented itself to him, in an equally fearless fashion. Of a vigorous temperament and endowed with unbounded activity and intellectual strength, Dr. Barlow found a wide field for his geological investigations, and his reports breathe that spirit of originality, of thought, and of personal care and attention, of minute petrographical and microscopical details, which were necessary in the study of the many areas of ore-deposits entrusted to him by the various directors of the Geological Survey under whom he wrought for the past twenty-five years. It was under Dr. Selwyn and Dr. Dawson, as well as under Dr. Low, that he was enabled to do his best work. In mining centres he was the welcome geologist and friend to be consulted, and his information both in the field and in the office was the final word that gave satisfaction to the various inquiries made covering the areas above mentioned. His loss is great, and his work was thoroughly good during the brief half-century of his existence. At the March (1914) meeting of the Canadian Mining Institute held in Montreal he was the retiring President, and he did much for the Institute and the mining fraternity to bring about close relations between the thoroughgoing geologist and the practical mining engineer, a relation of the greatest value in any community where the mineral resources of a country are of such vast import as in Canada, realizing as they do now an annual value of some 135,000,000 dollars. During the Twelfth International Congress of Geology held in Canada last year Barlow was a host in himself. In him Canada has lost a diligent and successful as well as honest and fearless geologist, whose convictions went before his personal advantages or aggrandisement in an unselfish aim to bring his chosen science and its value to the State to the forefront in an unblemished career.

H. M. Ami.

Seaford, Sussex.

NEWTON HORACE WINCHELL.

Born December 17, 1839. Died May 2, 1914.

Professor Newton Horace Winchell died on Saturday, May 2, in a hospital at Minneapolis (the city in which he lived). He was in active health and work up to a few days before his death (which resulted from a surgical operation). Professor Winchell was born in N.E. New York on December 17, 1839, and died in his 75th year. His great work was as State Geologist of Minnesota, for twenty-eight years (1872–1900). He was Founder and Editor of the *American Geologist*, which was published for eighteen years in Minneapolis (1888–1905). Since 1906 Professor Winchell was in charge of the Department of Archæology of the Minnesota Historical Society.

Minnesota Historical Society. Warren Upham,
May 18, 1914. *Secretary and Librarian.*